III

EMISSION INVENTORY

A. METHODOLOGY FOR ESTIMATING SHIP EMISSIONS

Ship Emission Inventory Design

Marine vessels represent a significant source of emissions in the SCAB. The design objective for the emission inventory to be used for this study was to develop a detailed, day-specific emission inventory of commercial ocean-going marine vessel (ship) activities in southern California waters that could be used in the model simulations to compare the two control strategies. This level of detail is essential to accurately assess the impact of marine vessel control strategies on overall ship emissions. To accomplish this requires the collection of ship-specific activity, engine characteristics, and emission factor information. Ship-specific information is needed because each ship entering and leaving southern California waters has a unique activity profile (ship course, speed, berthing, etc.) and a unique set of emission factors based on the size of the ship, its engines, and its activity profile while operating within southern California waters. The time period selected for this study was August 3-7, 1997. This time period was selected because high ozone levels were measured in southern California during that time, and the number and types of ships operating in southern California waters during that time provide a representative cross section of ships calling at southern California ports.

Sources of Data

TWG members collected pertinent data necessary for building the emissions inventory. The U.S. Navy at Point Mugu and the Port of Los Angeles obtained information on ship activity data from the Marine Exchange of Los Angeles and Long Beach (Pera, 1998, Garrett, 1998). Average distances for the different routes in and out of the ports designated as Northern, Southern, Western, and Catalina, traveled (cruising mode) by ships in the South Coast waters and calling on the ports were obtained from "Marine Vessel Emissions Inventory and Control Strategies" (Acurex report) prepared by Acurex Environmental (Acurex, December 12, 1996). Information on maneuvering and any shifting between berths that may have occurred on the episode days was obtained from the Port of Los Angeles (POLA) and the Port of Long Beach (POLB) (Garrett 1998, Kanter, 1998). The Pacific Merchant Shipping Association provided information on stack height and emission exit temperature for commercial ships (for each ship type). (Levin, 1998). The U.S. Navy provided activity data and emissions data for the navy vessels (Osborne, 1999). John J. McMullen Associates, Inc. (JJMA) developed the ship-specific engine characteristics from Lloyd's Register of Ships (Remley, 1998). Charlotte Pera, formerly of Acurex Environmental, developed the NOx emission factors for diesel engines (auxiliary and main propulsion) using ship emission data from Lloyd's Maritime Exhaust Research Programme (Pera, 1998). Stack emission factors for diesel engines were obtained from Lloyd's Maritime Exhaust Research Programme, for steamships were obtained from U.S. EPA, and for gas turbines were obtained from General Electric through JJMA (Remley, 1998).

Ship Activity Data

The types of ships included in the inventory assessment are ocean-going vessels calling on the San Pedro Bay Ports (Ports of Los Angeles and Long Beach) and U.S. Navy vessels. Fishing vessels, tugboats and other harbor vessels, and U.S. Coast Guard vessels are not included in this inventory. This section describes ship activity in each operating mode while traveling in South Coast waters.

- Identification of Ship Modes of Operation

Emissions from ocean-going vessels occur at different rates while cruising, maneuvering, hotelling, and shifting operating modes. Each mode needs to be defined and tracked to accurately assess emissions. Ocean-going vessels enter and exit the South Coast waters in cruise mode, which is associated with a speed of about 13 to 22 knots. Ships are required to reduce speed to 12 knots within the precautionary zone, which begins about three to 5 miles from the breakwater. About one mile from the breakwater, the ships slow down to about 5 knots to take on a pilot and are then assisted by tugboats and maneuvered into the harbor. Main engines and auxiliary boilers are used during cruising (including cruising in the precautionary zone) and maneuvering modes. While hotelling, auxiliary boilers and generators (auxiliary engines) are used. The emission inventory is developed for these modes of operation. A summary of the operational modes accounted for in this analysis is presented in Table III-1.

Table III-1
Operational Modes Addressed in the Emission Inventory

Mode	Direction
Cruise	Entry (Inbound)
Cruise	Exit (Outbound)
Precautionary Zone Cruise	Entry (Inbound)
Precautionary Zone Cruise	Exit (Outbound)
Maneuvering	Entry (Inbound)
Maneuvering	Exit (Outbound)
Hotelling	-

- Commercial Shipping Arrivals and Departures

The Marine Exchange provided ship arrival and departure information for the

August 3-7,1997 SCOS episode. According to the data from the Marine Exchange, there were a total of 87 ships with 63 arrivals and 62 departures during this 5-day period. Several ships arrived and departed outside the August episode period. A summary of these data is provided in Table III-2. As shown in Table III-2, the breakdown of ships by type was 47 Container ships, 11 tankers, 9 bulk carriers, 6 vehicle carriers, 3 each of bulk/container carriers, general cargo, refrigerated cargo, and passenger, and 1 each of chemical tanker and roll-on/roll-off container carrier. A more detailed summary is provided in Table B-1 provided in Appendix B. In Table B-1, the description on the ocean-going vessel calls in August 1997 at the POLA and POLB is provided using data from the Marine Exchange based on the following parameters: ship names, ship types, propulsion type (diesel, steamship, gas turbines), arrival and departure date, time, and direction of arrival and departure, arrival and departure gate. The majority of ship calls at the San Pedro Bay Ports were of the diesel engine propulsion type. There were very few calls made by vessels using gas turbine propulsion. Roughly 50 percent of the ships entered and departed the breakwater by Angel gate (POLA) and the other 50 percent by Queen gate (POLB).

Table III-2
Ship Counts for August 3-7, 1997 Episode Based on Ship Type, Propulsion Type, Engine Type, and Arrival and Departure Gate

Ship Type	Count	Propulsion Type	Count
Bulk Carrier	9	Diesel	74
Bulk/Container Carrier	3	Gas Turbine	2
General Cargo	3	Steam	11
Refrigerated Cargo	3		
Passenger	3	Diesel Engine Type	Count
Vehicle Carrier	6	2 Stroke	68
Container Carrier	47	4 Stroke	6
Chemical Tanker	1		
Tanker	11	Gate	Count
RORO Container	1	Angel	78
TOTAL	87	Queen	96

- Maneuvering, Berthing and Hotelling

Information on maneuvering and any shifting between berths that may have occurred on the episode days was obtained from POLA and POLB. The POLA and POLB Wharfinger agency provided data on hotelling and maneuvering activities for the episode days. Default times were used from the Acurex report (Acurex, December 12, 1996), whenever ship specific information was not available. To calculate time spent hotelling, we subtracted the actual maneuvering times from the total time spent in port.

- U.S. Navy Vessel Inventory

The U.S. Navy provided day-specific ship activity data for navy vessels traveling in the SCOS97 domain north of Point conception to south of the Mexican border during the August episode (Osborne, 1999, Remley, 1998). The information on ship class, ship type, average ship speed (knots), ship positions (latitude and longitude), port visited (at pierside), time duration (hrs), start date, end date, and emission rates (kg/hr) for NOx was provided for each navy vessel (See Appendix B, Table B-2). The majority of the navy vessel activity during the August episode occurred near the port of San Diego.[4]

- Port Hueneme

Ventura County Air Pollution Control District provided ship activity data for Port Hueneme on the August episode days (McGaugh, 1999). There were eight commercial ships arriving and departing during the August episode. Ship-specific information for the vessels traveling to this port was not available to us. Therefore emissions for Port Hueneme were not included as part of this analysis. There was no U.S. Navy vessel activity at Port Hueneme during the August episode.

- Transiting Ships

Transiting ships are those vessels that travel northbound or southbound along the coast without stopping at a port. The U.S.Navy Point Mugu Range Surveillance (1997) database was used to obtain information on transiting ships (Rosenthal, 1999). The data indicated that there are very few transiting ships traveling along the Santa Barbara Channel but not coming into the ports of Los Angeles and Long Beach, approximately 3 or 4 a month. In addition, the route for transiting vessels may be very far offshore, in some cases outside the overwater boundary. Therefore, for the purposes of the comparative technical analysis of the air quality impacts between the two control options, it was agreed that the transiting ship emissions could be ignored.

Ship Machinery and Operational Characteristics

- Speed Power Curves

The power required to drive a ship varies with ship speed, cubed. In this study we used speed-power curves developed by JJMA for commercial ships (Pera, 1998, Remley, 1998). The JJMA curves were very similar to the ship speed cubed relationship.

[4] The emission inventory for Navy vessels is included in the report for informational purposes. The data was not included in the emission reduction estimates, gridded emissions or the model simulations for the comparative analysis as the data had not been completely reviewed prior to performing the analyses.

- Stack Information

The Pacific Merchant Shipping Association provided information on stack height and exit temperature for commercial ships (for each ship type). Because the stack information specific for each ship category was not available, the ships were assigned to two different categories based on the propulsion and energy generation plant configuration and average stack parameters (Levin 1998). A summary of the stack parameters is presented in Table III-3 below.

Table III-3
Stack Parameters for Container and Tanker Ship Type Categories.

	Stack Height* (meters)	Stack Diameter (millimeters)	Stack Exhaust Temp (^{0}C)	Stack Exhaust velocity (meters/second)
Container Category	37.6	2012	222	25.8
Tanker Category	32.9	1705	306	23.4

*Stack height is height of stack above the water surface.

- Engine Characteristics

Ship-specific engine characteristics were used in developing the marine vessel inventory based on the information provided by JJMA. Some of the ship-specific characteristics were 1) actual horsepower for each ship, 2) actual kilowatt (kW) information for each generator (auxiliary engine), 3) steam ship-specific fuel consumption, and 4) propulsion type-specific emission factors (diesel, steamship, turbine).

- Ship Speed

Operating speeds of ships at sea vary with the size and type of vessels and the mode of propulsion. For the base-case, ship-specific cruising speed data for this analysis were available. The TWG obtained actual speed data for 60 days (9/22/98 through 11/22/98) for ships cruising in South Coast waters. This comprised approximately 1600 records. The actual open ocean cruising speed was determined using radar readings taken by the port when the ship was 25 miles off shore. At that distance, ships are operating at their open ocean cruising speed. The actual speeds were available from radar readings for over half of the ships identified as operating in South Coast waters during the August episode.

These data indicated that on the average the actual cruising speed was less than the ship's design speed (ARCADIS, May28, 1999 and Lloyds, 1995). It also demonstrated that the difference between actual and design speed varied with each ship type. Generally, the largest variation in speed was for passenger vessels. The actual speed of the slowest and fastest vessels within each type differed by as much as 10 knots for passenger vessels and about 8 knots for container vessels. However, most of the ships within a given ship type category fell within a narrow 3-4 knot range of cruising speed.

We took advantage of this relationship by using the actual speed information to calculate a speed correction factor (SCF) by ship type. The SCF (for that particular ship type) was applied to the design speed for the ships traveling on the episode days where actual speed information was not available. Table III-4 summarizes the average actual versus the average design speed by ship type. Records that did not include a design speed or where the design speed was recorded as "0.1" (indicating missing data according to the Marine Exchange) were deleted. All the data records with speed less than 5.5 were considered erroneous and were deleted.

Table III- 4
Comparison of Actual Versus Design Speeds for Typical Ship Types

Route	Vessel Information	TYPE "C"	TYPE "P"	TYPE "T"
All	Average MAREX Speed	17.90	13.60	13.68
	Average Design Speed	19.58	20.40	15.31
	Vessel Count	1341	111	231
	Avg. count per day	22	2	4
	Speed Correction Factor	0.91	0.67	0.89
Arrivals	Average MAREX Speed	17.56	13.21	13.51
	Average Design Speed	19.60	20.39	15.30
	Vessel Count	665	55	112
	Maxspeed Diff.	Hanjin Malta (14.89)	Holiday (14.01)	Columbia (11.48)
Departures	Average MAREX Speed	18.23	13.97	13.84
	Average Design Speed	19.56	20.41	15.32
	Vessel Count	676	56	119
	Maxspeed Diff.	Luhe (11.93)	Mercury (14.94)	Columbia (11.96)

Notes: "Design Speed" is Lloyd's design speed. "C" represents Cargo carriers such as containers, auto carriers, and breakbulk. "P" represents passenger vessels and "T," liquid bulk carriers. "Maxspeed Diff." is the difference of the design speed and MAREX speed.

In the precautionary zone, ships are required to travel at 12 knots. As a general practice, they begin slowing down about three to 5 miles before the breakwater so that they are at the mandatory 5-knot speed when entering the breakwater (ACUREX, 1996). The TWG agreed to not account for the slowing down between 12 and 5 knots, as this would probably be in the "noise" of the model and for the comparative analysis, would not affect the comparison between the two control strategies. Therefore, it was assumed that ships are cruising at 12 knots in the precautionary zone and 5 knots in the breakwater.

- Engine Loads

Engine Loads differ with every mode of operation. Cruise mode is associated with an engine load of approximately 80 percent maximum continuous rating (MCR). For precautionary zone cruising the following assumptions were made. In the precautionary zone, ships are required to travel at or below 12 knots. The percent MCR at 12 knots was estimated using the ratio of 12 knots to the actual or design speed of each ship. The implied percent power was calculated using 80 percent of the speed ratio cubed. During maneuvering mode, information from the Acurex report (Acurex, December 12, 1996) was used to obtain the percent MCR at an average speed of 5 knots. Maneuvering at 20 percent MCR was assumed for bulk carriers, general cargo, and tankers. Container ships were assumed to maneuver at 10 percent MCR, and remaining ships were assumed to maneuver at 15 percent MCR. Information on engine loads within the breakwater was very difficult to obtain and so it was recommended by the TWG to not pursue it further.

- Emission Factors

Emission factors in grams per kilowatt-hour (g/kWh) of energy output were used to estimate NOx emissions from main engines and generators (auxiliary engines). The TWG agreed to use emission factors based on energy output (for example grams of NOx/kWh) for the following reasons: 1) there is some uncertainty in the brake-specific fuel consumption (BSFC) factor needed to calculate the emission factor based on fuel consumption, 2) very limited information is available on projected fuel usage in future years, and 3) the energy output based emission factors are independent of fuel consumption rates and therefore eliminate the need to account for future changes in ship fuel efficiencies (ARCADIS, May 6, 1999, and ARCADIS May 28, 1999).

The cruising and maneuvering main engines (diesel) NOx emission factors at different engine loads were developed by ARCADIS for NOx as shown in Table III-5. Average NOx emission factors for slow and medium speed engines were estimated to be 17 and 12 g/kWh (87 and 57 kg/tonne fuel), respectively. The only distinction made for NOx was between slow and medium speed emission factors (ARCADIS, May 6, 1999 and Lloyds, 1995).

Table III-5
NOx Emission Factors in grams/kWh

%MCR	80%	40%	35%	20%	15%	10%
Slow Speed NOx	17.32	18.04	18.13	18.41	18.5	18.59
Medium Speed NOx	12.81	14.03	14.18	14.64	14.79	14.94

For generators, medium speed emission factors were assumed for all modes. For auxiliary boilers, emission factors in pounds per hour were used (ARCADIS, May 6, 1999, ACUREX 1996, ARCADIS, May 28, 1999). The NOx emission factors for steamships were obtained from the U.S. EPA AP-42 document. (U.S. EPA, 1985) The gas turbines emission factors were developed by GE and provided by JJMA (Remley, 1998).

Emission Calculations

Base Case Inventory

- Commercial Vessels

This section summarizes the preliminary estimates of NOx emissions for the August 3-7,1997 SCOS episode (See Table III-6). To calculate emissions, we used the total amount of time spent cruising, maneuvering, and hotelling in the SCAB waters. To estimate main engine emissions, the main engine horsepower for each ship was multiplied by the energy output factor (g/kWh) and by the total number of hours estimated for that mode (i.e., cruising, precautionary zone cruising, etc). For example, for cruise mode, 80 percent of the actual horsepower for each ship was multiplied by the time spent in the entry and exit cruise modes, and the emission factors. Several variables are needed to estimate the emissions associated with each of these modes. As an example, to estimate the emissions associated with the in-bound or entry cruising, the following data are necessary: entry cruise distance, actual speed, engine horsepower (Lloyds), cruise speed at 80 percent MCR power, entry cruise hp-hr, entry cruise kWh, and EMSFAC cruise g/kWh. This is represented by the following equation:

*(Entry Cruise Distance/speed) * (80% MCR of actual HP value) * (Emission factor g/kWh) = NOx emissions*

For generators, the following approach was used to estimate NOx emissions. The generators were assumed to be medium speed engines. The generator rated kW (largest size generator for each ship) was multiplied by the load factor (80 percent for cruising, precautionary zone cruising, and maneuvering and 55 percent for hotelling) and the time spent in each mode and medium speed engine emission factors.

For auxiliary boilers, we used the methodology adopted in the ARCADIS report (ARCADIS May 28, 1999). We estimated auxiliary boiler emissions in cruising, maneuvering, and hotelling modes.

For steamships, the emission calculations are slightly different since the steamship emissions are based on the ship's boiler fuel consumption. The propulsion and auxiliary engines (generators) in the case of steamships are steam turbines that do not have any emissions. The emissions are from the main boilers, which generate the steam that powers the turbines. For steam ships, emission factors for residual fuel (55.8 lbs. NOx/1000 gallon fuel for cruise mode and 36.8 lbs. NOx/1000 gallon fuel for hotelling) were used. The emission factors vary with mode because of the load on the main boilers. While cruising, the boilers are highly loaded and so produce more NOx per gallon of fuel burned than when they are in port and are not as highly loaded.

Based on the energy output methodology, approximately 115 tons (23 tons per day) of NOx was estimated from ship activity for the 5-day August episode. This comprehensive estimate takes into account the main engine/boiler-cruising and maneuvering emissions; generator (auxiliary engine)-cruising, maneuvering, and hotelling emissions; and auxiliary boiler-maneuvering and hotelling emissions. As a comparison, the Acurex Report (December 12, 1996) estimated emissions of 21.6 tons per day (TPD) and the 1995 Annual Average emissions inventory for the SCAB is 29 TPD.

Table III-6
Baseline NOx Emissions (tons) for the Existing MAREX
In-Bound and Out-Bound Shipping Lanes for 5-Day August Episode

Main Engines						Auxiliary Boilers		
Entry Cruise	Exit Cruise	Entry PZC	Exit PZC	Entry Maneuvering	Exit Maneuvering	Entry All Cruise	Exit All Cruise	Hotelling + Maneuvering
31.5	38	3.1	2.6	2.3	2.0	0.2	0.2	7.5

Generators							Total NOx
Entry Cruise	Exit Cruise	Entry PZC	Exit PZC	Entry Maneuvering	Exit Maneuvering	Hotelling	
1.7	1.9	0.4	0.4	0.7	0.6	22.1	115.4 (2.3 tpd)

- Naval Ship Emissions

This section provides the preliminary U.S. Navy vessel NOx emission estimates for the August 3-7, 1997 SCOS episode. These emissions pertain to cruising mode only. Average ship speed is calculated from ship's log data for the respective time intervals. While in port, navy vessels are in a cold iron status and engines are completely shut down, therefore, there are no exhaust emissions. The NOx emissions from U.S. Navy vessels for the entire SCOS domain were 15 tons for the entire August episode.

Emission Estimates for the Base Case and Speed Reduction Modeling Scenarios

Emission estimates were prepared for the three voluntary speed reduction scenarios and the base case. Estimates were not prepared for the proposed relocation of the shipping lane due to the complexity of the calculations and resource availability. For the proposed shipping lane, only the gridded emissions estimate was prepared. (See the next section B, "Gridded Emissions Model.")

The three potential speed reduction scenarios have been discussed previously. To briefly recap they are:
1) Scenario #1: extending the precautionary zone 12-knot speed limit to 20 miles;
2) Scenario #2: extending the precautionary zone 12-knot speed limit to the SCAB overwater boundary; and
3) Scenario #3: a speed limit of 15-knots between the precautionary zone and the SCAB overwater boundary.

In Table III-7 the estimated emissions for the August 3-7, 1997 episode for the base case (uncontrolled) and each of the speed reduction scenarios are presented. Only the emissions in the SCAB are included in the estimates. Total emissions are presented as well as the emissions for the main engines, generators, and auxiliary boilers.

Table III-7
NOx Emissions for Base Case and Speed Reduction Scenarios

Scenario	Main Engines	Generators (Tons)	Auxiliary Boiler	Total (Tons)
Base Case	79.5	27.9	8.0	115.4
Scenario #1	66.8	28.5	8.0	103.3
Scenario #2	44.8	29.5	8.1	82.5
Scenario #3	57.0	28.7	8.0	93.7

The estimated average transit time for specific ship types under the speed reduction control scenarios #1, #2, and #3 are summarized in Table III-8 below.

Table III-8
Average Transit Times (minutes) for Specific Ship Types Under Speed Reduction Control Scenarios for August 4, 1997

	Basecase					Scenario 1				
Type	Cruise Entry	Cruise Exit	PZC Entry	PZC Exit	Total	Cruise Entry	Cruise Exit	PZC Entry	PZC Exit	Total
BBU(5)	180	176	35	25	416	120	109	94	102	425
GGC (2)	156	159	39	30	384	102	102	102	102	408
GRF (2)	123	126	30	24	303	78	78	102	102	360
MPR (2)	183	204	40	32	458	117	129	111	111	468
MVE (2)	150	144	33	24	351	99	90	102	101	392
TTA (3)	154	162	38	30	384	98	108	102	102	410
UCC (20)	120	126	34	25	304	78	80	102	102	362

Table III-8 (cont.)

	Scenario 2					Scenario 3				
Type	Cruise Entry	Cruise Exit	PZC Entry	PZC Exit	Total	Cruise Entry	Cruise Exit	PZC Entry	PZC Exit	Total
BBU(5)	0	0	199	222	421	180	176	35	25	416
GGC (2)	0	0	222	222	444	156	162	39	30	387
GRF (2)	0	0	216	216	432	150	156	30	24	360
MPR (2)	0	0	222	234	456	183	204	42	30	459
MVE (2)	0	0	234	221	455	162	156	33	24	375
TTA (3)	0	0	222	232	454	156	166	38	30	390
UCC (20)	0	0	224	228	452	155	161	34	25	374

Notes: ()=Number in Parenthesis represents the count for the August 4, 1997. Totals may not match due to rounding. The following abbreviations are used to identify the ship types: Bulk Carrier (BBU); Bulk/Container Carrier (BCB); General Cargo (GGC); Refrigerated Cargo (GRF); Passenger (MPR); Vehicle Carrier (MVE); Chemical Tanker (TCH); Tanker (TTA); Container Carrier (UCC); and RORO Container Carrier (URC).

To determine transit times for the proposed shipping lanes, the following methodology was used. First, only those ships arriving from the north (52 ships) or departing to the north (47 ships) were used in the calculation since the proposed change in the shipping lane only affects this route. The next step was to disregard those ships transiting within the SCOS97 domain at the start or end of the August 3-7 episode, since transit times from the edge of the domain to port or vice versa could not be determined for those ships. For the remaining ships (33 arriving from the north and 30 departing to the north), the difference in transit times between the current and proposed shipping lanes was determined; these values were then averaged. The results are summarized in Table III-9.

Table III-9
Difference in Average Transit Times (minutes) for the Base Case and Speed Reduction Scenarios for the Proposed Shipping Lanes

	Scenario #1	Scenario #2	Scenario #3	Proposed Shipping Lane
Arrivals	30	62	27	63
Departures	33	67	32	57

B. GRIDDED EMISSIONS MODEL

The ship activity and emission factor data for August 3-7, 1997, were provided as input to a computer model to calculate gridded ship NO_x emissions for the modeling region (described below). Gridded emission totals for the region and for the South Coast waters only were calculated for the base case (current shipping lanes), the proposed shipping lanes, and for each of three voluntary speed reduction scenarios. Below we briefly describe the model and domain used, and then provide the gridded emission totals.

Model Domain and Description

The model first establishes the domain to be gridded, based on user-specified information on the desired origin, grid resolution, and number of cells in each direction. For the ship gridding, the domain was defined by the following:

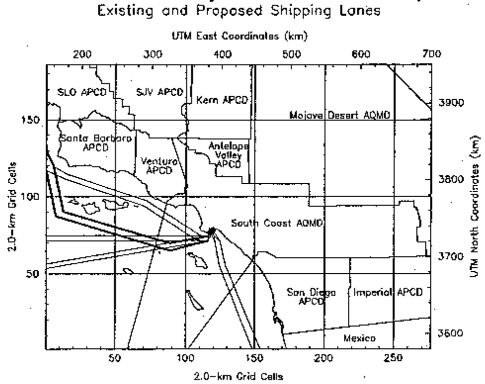
Origin:	150 km UTM East 3580 km UTM North
Grid cell resolution:	2 km
Number of grid cells in east-west direction:	275
Number of grid cells in north-south direction:	185

Figure III-1 shows the domain used. An additional requirement for this study was the need to determine shipping emissions within the South Coast waters only; this region is indicated in the figure by the offshore lines perpendicular to the coastline at the boundaries of the South Coast.

After the domain has been established, the coordinates for the various paths (North, South, West, and Catalina routes) are then read in, and for each cell that the path intersects the cell coordinates and distance in that cell are determined. For the proposed shipping lanes scenario, the model is simply re-run with the coordinates for the existing lane replaced by those from the proposed lanes.

Figure III-1
Gridded Shipping Inventory Domain
Proposed Shipping Lanes in Bold
South Coast Waters Area Indicated by Offshore Lines Perpendicular to Coastline

Existing and Proposed Shipping Lanes



The following information (described in Section III.A) is needed for each ship to create the gridded ship emission inventory:

- ship name
- speed
- cruising power
- maneuvering power
- vessel type
- engine type
- number of cylinders
- arrival information (gate, direction, date, time)
- departure information (gate, direction, date, time)
- entry and exit maneuvering times
- stack parameters
- emission factors at different power levels

For ships, which entered port, the entry path is determined and the ship is taken backward in time from the entry port along the entry path, using the port entry time. This step includes time spent maneuvering in port. The emissions in each grid cell are determined from the ship speed, distance of the route within the cell, and the appropriate emission factor. Similarly, ships which left port are taken forward in time along the exit path. The emissions for the hotelling time in port are added to the port cell data.

Gridded Emission Inventories

The gridded emissions model was used to calculate ship NO_x emissions for the modeling region and for the South Coast waters only, for the base case (existing shipping lanes), the proposed shipping lanes, and for each of three voluntary speed reduction scenarios. The speed reduction scenarios have been described previously, however they can be summarized as follows:

Speed Reduction Scenario #1: Based on the current shipping lanes with the precautionary zone speed limit of 12 knots extended to 20 miles.

Speed Reduction Scenario #2: Based on the current shipping lanes with the precautionary zone speed limit of 12 knots extended to the overwater boundary of the SCAB waters.

Speed Reduction Scenario #3: Based on the current shipping lanes with the existing 12-knot precautionary zone. A speed limit of 15 knots is applied between the overwater boundary of the SCAB waters and the precautionary zone.

Tables III-10 and III-11 below summarize ship NO_x emission totals for August 3-7, 1997, for the modeling region and SCAB waters only, respectively.

Table III-10
Gridded Ship NO_x Emissions Totals (tons) for August 3-7, 1997
(Entire Modeling Region)

Scenario	*Aug. 3*	*Aug. 4*	*Aug. 5*	*Aug. 6*	*Aug. 7*	*Aug. 3-7*	*Avg. change per day from base case*
Current Shipping Lane *(Base Case)*	60.47	67.35	34.81	45.21	57.98	265.82	
Proposed Shipping Lane	65.09	72.31	37.30	49.00	62.38	286.08	4.05
Speed Reduction Scenario #1	57.67	63.18	32.37	44.10	52.63	249.95	-3.17
Speed Reduction Scenario #2	53.39	58.68	31.06	41.56	45.98	230.67	-7.03
Speed Reduction Scenario #3	56.55	61.86	32.05	43.41	50.97	244.84	-4.20

Table III-11
Gridded Ship NO_x Emissions Totals (tons) for August 3-7, 1997
(South Coast Air Basin Waters Only)

Scenario	*Aug. 3*	*Aug. 4*	*Aug. 5*	*Aug. 6*	*Aug. 7*	*Aug. 3-7*	*Avg. change per day from base case*
Current Shipping Lane *(Base Case)*	26.14	30.17	15.12	18.71	24.64	114.78	
Proposed Shipping Lane	26.73	30.80	15.42	18.99	25.37	117.31	0.51
Speed Reduction Scenario #1	23.59	26.38	12.57	16.92	20.50	99.96	-2.96
Speed Reduction Scenario #2	19.62	22.32	10.78	13.75	15.64	82.11	-6.53
Speed Reduction Scenario #3	22.31	25.13	12.35	16.15	18.94	94.88	-3.98

As shown by Table III-11, NO_x emissions within the SCAB waters vary significantly by day, due to differences in activity. However, the NO_x tonnage reductions within the SCAB waters are greatest for voluntary speed reduction scenario #2, and are slightly higher for the proposed lanes than for the existing lanes. These directional changes are consistent across all days, although their magnitude is not.

During the stakeholder meetings, a question arose as to why there are larger differences in daily emissions in the SCOS97 domain than in the South Coast waters for the different speed reduction scenarios, since those scenarios only change the maximum speed in different parts of the South Coast waters. It turns out that this difference is simply an artifact of reporting emissions on a daily basis. Any speed reduction in the South Coast waters reduces the amount of time that a ship spends in the rest of the SCOS97 domain for any given day.

As an example, consider one ship in particular, the Tundra King. The Tundra King arrived at the port of Los Angeles on August 4, 1997 at 0640 from the north, and departed to the south that same day at 1935. The average cruise speed was 18.2 knots. Table III-12 summarizes when the Tundra King reached different locations. The only information we have on the location of the Tundra King are the times of arrival and departure from port. The other times are determined by the assumed speed, which varies with scenario.

Table III-12
Estimated Arrival and Departure Times for the Tundra King

	Base Case	Speed Reduction Scenario #1	Speed Reduction Scenario #2	Speed Reduction Scenario #3
Arrives in port	0640 on 8/4	0640 on 8/4	0640 on 8/4	0640 on 8/4
Arrives South Coast waters	0401 on 8/4	0330 on 8/4	0255 on 8/4	0334 on 8/4
Arrives in SCOS domain	2246 on 8/3	2214 on 8/3	2140 on 8/3	2219 on 8/3
Leaves port	1935 on 8/4	1935 on 8/4	1935 on 8/4	1935 on 8/4
Leaves South Coast waters	2216 on 8/4	2239 on 8/4	2322 on 8/4	2243 on 8/4
Leaves SCOS domain	0046 on 8/5	0109 on 8/5	0152 on 8/5	0113 on 8/5

From the above table, we can see that the Tundra King spends the same amount of time in the SCOS97 domain outside of the SCAB waters for all scenarios: 5 hours, 15 minutes on the way in, and 2 hours, 30 minutes on the way out. However, the amount of time spent in the SCOS97 domain outside of the SCAB waters *on August 4* varies among the scenarios. This explains the larger differences in daily emissions in the SCOS97 domain than in the SCAB waters for the different speed reduction scenarios.

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IV

TRACER DISPERSION STUDY

As discussed previously, the stakeholders funded a tracer dispersion study to provide sound scientific data on the transport of vessel emissions from ships traversing the shipping channel. The tracer study was conducted during the SCOS97 to take advantage of the enhanced data collection efforts associated with SCOS97. The overall objectives of the tracer study were to:

1. provide regulatory agencies and stakeholder organizations with scientifically valid information for decision making regarding the impact of atmospheric emissions from the current and proposed shipping lanes on ozone episodes in the South Coast Air Basin;
2. provide data to validate meteorological models; and
3. the extent possible, conduct a study which will utilize and augment SCOS97.

The primary objective of the study was to obtain direct scientific evidence regarding the trajectory of emissions from vessels transiting the coast and the relative impact of shipping emissions on onshore air quality, specifically from the current and proposed shipping lanes. While ship emissions include several pollutants (SO_x, PM, CO, and NO_x), NO_x emissions from ships were subsequently identified by the technical working group as the pollutant of focus, since the 1994 and 1997 SIP measure M13 requires reductions in NO_x emissions from marine vessels. A secondary objective was to assess the ability of meteorological models to simulate the relevant physical processes that take place during transport of emissions from the shipping lanes to onshore locations in southern California. Successful validation of meteorological models would allow use of those models to numerically assess the relative difference in impacts from shipping emissions for a relocated shipping lane and from voluntary speed reduction scenarios.

The following sections provide a discussion of the tracer study and how the resulting data were analyzed, including quality assurance of the data and how the data were normalized to account for differences between compounds and releases.

A. TRACER STUDY TESTS

The tracer study design entailed releasing known quantities of tracer gases at prescribed times and locations with the release location reflecting the distance offshore of the existing vessel traffic lanes as well as the proposed relocated traffic lanes further offshore. Monitoring equipment on land and offshore then recorded the concentrations of tracer gases reaching the shore. The feasibility of this type of overwater/coastal area tracer study was established by a review of inert gaseous atmospheric tracer studies for the period of 1970-1990 (Tracer ES&T 1997a). The tracer releases and sampling as well as the targeted meteorology, sampler locations, tracer selection, and field operational logistics are described in a series of deliverables to the stakeholders (Tracer ES&T 1997a, 1997b, 1997c, 1998). In this section we briefly summarize key aspects of the tracer study, however the reader is referred to the deliverables for more detail on the study design and scope.

The tracer experiments were targeted for high ozone episodes in the South Coast Air Basin. Ideal episodes were identified as those with weak on-shore flow combined with very warm and clear skies. Both passive and sequential time-averaging samplers were employed during the study. Thirty (30) locations had automated sequential samplers (called BATS) which collected concurrent 2-hour or 1-hour sequential air samples throughout a 46-hour test window. Passive samplers (called CATS) were employed at 21 locations; these samplers collected approximately 24 hour averaged samples. Four sites had co-located CATS and BATS samplers. Figure IV-1 shows the sampling network; Table IV-1 lists the site locations.

Figure IV-1
Sampling Network

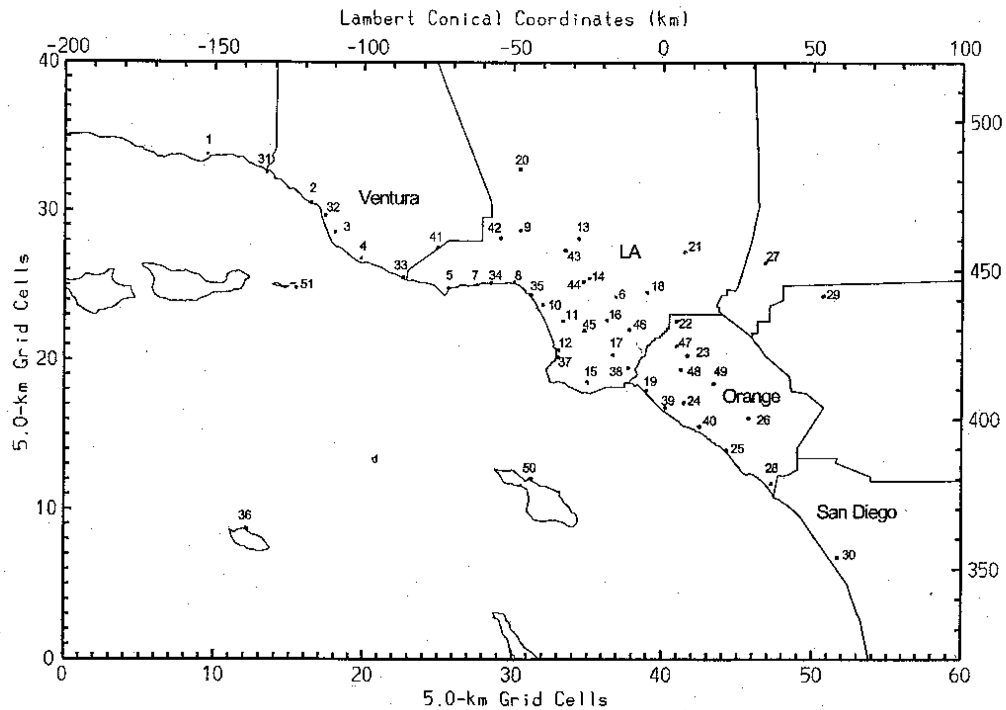


Table IV-1
Sampler Locations

Site No.	Site Location	Sampler Type(s) and Averaging Times		
		BATS		CATS
		1-hour	2-hour	24-hour
1	Santa Barbara		✓	
2	Ventura		✓	
3	Oxnard Airport		✓	
4	Pt. Mugu Naval Air Station		✓	
5	Pt. Dume Fire Station		✓	
6	Vernon Fire Station	✓		
7	Malibu Beach Fire Station		✓	
8	Castellemare Fire Station	✓		
9	Reseda SCAQMD Station		✓	
10	Marina Del Rey (LA Sheriff's Dept.)	✓		✓
11	Hawthorne SCAQMD Station	✓		✓
12	Redondo Beach Fire Station	✓		✓
13	Burbank SCAQMD Station		✓	
14	Westlake Fire Station	✓		
15	Port of Los Angeles	✓		✓
16	Lynwood SCAQMD Station		✓	
17	Long Beach SCAQMD Station		✓	
18	Pico Rivera SCAQMD Station	✓		
19	Huntington Beach Fire Station		✓	
20	Santa Clarita SCAQMD Station		✓	
21	Azusa SCAQMD Station		✓	
22	La Habra SCAQMD Station		✓	
23	Anaheim SCAQMD Station		✓	
24	Costa Mesa SCAQMD Station		✓	
25	Laguna Beach Fire Station		✓	
26	El Toro Fire Station		✓	
27	Upland SCAQMD Station		✓	
28	San Clemente Fire Station		✓	
29	Rubidoux SCAQMD Station		✓	
30	Oceanside SDAPCD Station		✓	
31	Rincon			✓
32	Harbor Blvd. (Ventura)			✓
33	Leo Carrillo			✓
34	Las Flores Canyon Rd. (Malibu)			✓
35	Crescent Park (Santa Monica)			✓
36	San Nicolas Island			✓
37	Miramar Park (Torrance)			✓
38	Los Altos Plaza Park (Long Beach)			✓
39	Manning Park (Huntington Beach)			✓
40	Grant Howard Park (Newport Beach)			✓
41	Westlake			✓
42	Warner Ranch Park			✓
43	Weddington Park (Universal City)			✓
44	Loyola High School (Los Angeles)			✓
45	Memorial Hospital of Gardena			✓
46	Bellflower Fire Station			✓
47	John Marshall Park (Anaheim)			✓
48	Community Center Park (Garden Grove)			✓
49	Frontier Park (Tustin)			✓
50	Santa Catalina Island			✓
51	Anacapa Island			✓

Five perfluorocarbon tracers (PFTs) were chosen for use in the study. PFTs were chosen as tracers because of their low global background levels and their superior detectability. These factors allow tracer tests to be conducted using minimal amounts of the PFTs, which result in substantial cost savings over other tracers. In addition, PFTs are physically and chemically inert. This prevents losses in the atmosphere and means that they are environmentally safe. The specific chemical names, abbreviations, and molecular weights for those PFTs used in this study are provided in Table IV-2 below.

Table IV-2
Perfluorocarbon Tracers

Tracer Chemical Name	Abbreviation	Molecular Weight (g/mole)
Perfluoromethylcyclopentane	PMCP	300
Perfluoromethylcyclohexane	PMCH	350
Perfluoro-1,2-dimethylcyclohexane	PDCH	400
Perfluorotrimethylcyclohexane	PTCH	450
Perfluorodimethylcyclobutane	PDCB	300

Quality assurance activities performed by the contractor included internal performance audits and field visits, contamination and leak checks, blank and co-located sample analysis, and tracer purity checks.

Two background studies were conducted to prepare for the field study. Each background study utilized CATS samplers only. The samplers were placed to detect if there were any upwind sources of the tracers planned for use in the field study. The tracer concentrations obtained during the background studies were also used by the contractor to report field study concentrations above background levels.

Following the background tests, a series of three tracer tests were conducted to measure the atmospheric impacts from releases in the existing and proposed shipping lanes. A fourth test was cancelled in progress when the oil spill response vessels used to release the tracer gases were recalled to port due to an oil spill in Santa Barbara. Table IV-3 summarizes the tests. For the tests, two release configurations were employed. One was a moving point source configuration wherein tracer gases were released continuously from vessels moving simultaneously along the existing and proposed shipping lanes. The other release configuration was a “fixed point” configuration. In this configuration the tracer gases were released from a stationary or fixed point within each shipping lane and the tracer gases were continuously released for a specified period of time.

Table IV-3
Summary of Tracer Tests

Test #	Tracer Release Date
1	August 23, 1997
2	September 4, 1997
3	September 29, 1997 *(cancelled)*
4	October 4, 1997

For test #1, the five tracer gases were released from three different vessels (see Figure IV-2). Two tracers were released from a moving source in the current shipping lane. Two separate tracers were released from a moving source in the proposed shipping lane. The remaining tracer was released as a stationary point source at the separation point common to both shipping lanes. Table IV-4 summarizes tracer test #1.

Figure IV-2
Tracers and Release Locations for Test #1

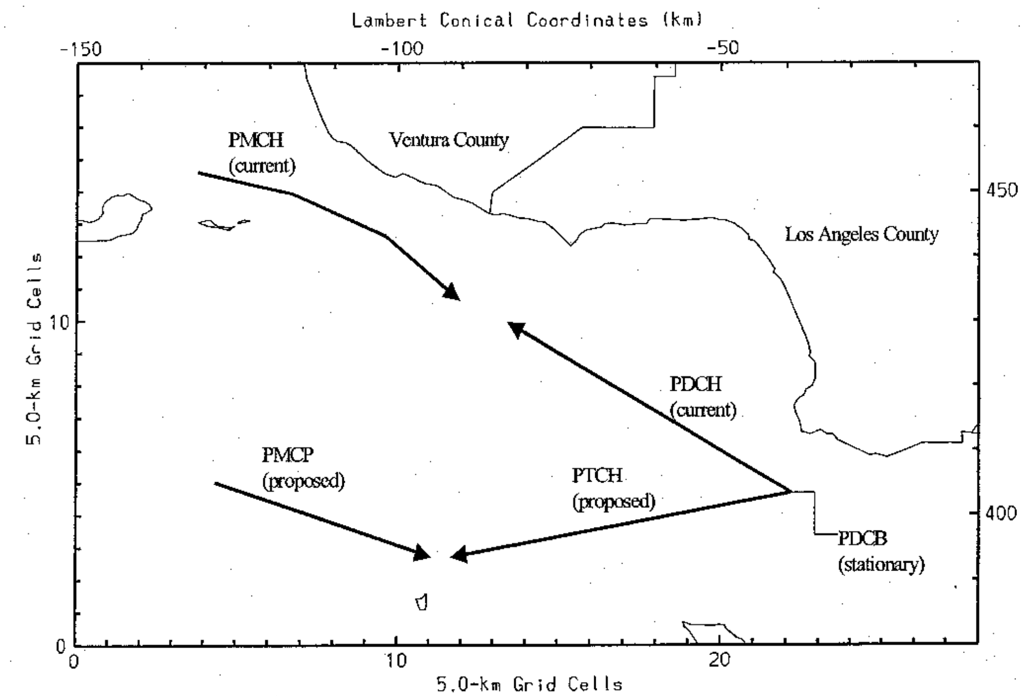


Table IV-4
Summary of Tracer Test #1
(August 23-24, 1997)

Shipping Lane	Tracer	Release Type	Release Start Time	Release End Time	Tracer Released (g)	Average Release Rate (kg/hr)	Average Vessel Speed (mph)
Current	PDCH	Moving	0400	0700	2,910	0.97	10.7
Proposed	PTCH	Moving	0401	0655	3,085	1.06	11.6
Both	PDCB	Stationary	0408	0608	3,215	1.61	0.0
Current	PMCH	Moving	1200	1500	2,835	0.95	9.6
Proposed	PMCP	Moving	1058	1400	2,720	0.90	7.3

Five tracers were also released for test #2, from two different vessels (see Figure IV-3). Except for minor differences in release times, the tracer release details were the same as for test #1. Two tracers were released from a moving source in the current shipping lane. Two separate tracers were released from a moving source in the proposed shipping lane. The remaining tracer was released as a stationary point source at the separation point common to both shipping lanes. Table IV-5 summarizes tracer test #2.

Table IV-5
Summary of Tracer Test #2
(September 4-5, 1997)

Shipping Lane	Tracer	Release Type	Release Start Time	Release End Time	Tracer Released (g)	Average Release Rate (kg/hr)	Average Vessel Speed (mph)
Current	PDCH	Moving	0755	1055	3,470	1.16	12.4
Proposed	PTCH	Moving	0750	1055	2,800	0.91	10.3
Both	PDCB	Stationary	0220	0400	940	0.56	0.0
Current	PMCH	Moving	1200	1440	2,350	0.88	11.9
Proposed	PMCP	Moving	1200	1430	2,990	1.20	10.6

The plan for test #3 was to release the five tracer gases from two vessels on September 29, 1997. However, the test was cancelled when the vessels (which were both provided by Clean Coastal Waters, an oil spill response company) were recalled due to an oil spill in Santa Barbara.

For test #4, all five tracer gases were released from two different vessels (see Figure IV-4). Two tracers were released as stationary point sources within the current shipping lane. Two separate tracers were released as stationary point sources, at two different locations (one from the proposed shipping lane, the other was off-course due to human error by the vessel's Captain). The remaining tracer was released as a moving source within the current shipping lane. Table IV-6 summarizes tracer test #4.

Table IV-6
Summary of Tracer Test #4
(October 4-5, 1997)

Shipping Lane	Tracer	Release Type	Release Start Time	Release End Time	Tracer Released (g)	Average Release Rate (kg/hr)	Average Vessel Speed (mph)
Current	PDCH	Stationary	0600	0800	2,970	1.49	0
Off Course	PTCH	Stationary	0600	0800	2,950	1.48	0
Current	PDCB	Moving	0400	0600	3,285	1.64	17.6
Current	PMCH	Stationary	1100	1300	3,255	1.63	0
Proposed	PMCP	Stationary	1100	1300	3,190	1.60	0

Following each tracer test, the collected air samples were shipped to Brookhaven National Laboratory (BNL) for analysis to determine the concentration of each tracer gas from each sample. In the section below we describe the tracer measurements and analysis of the tracer data.

Figure IV-3
Tracers and Release Locations for Test #2

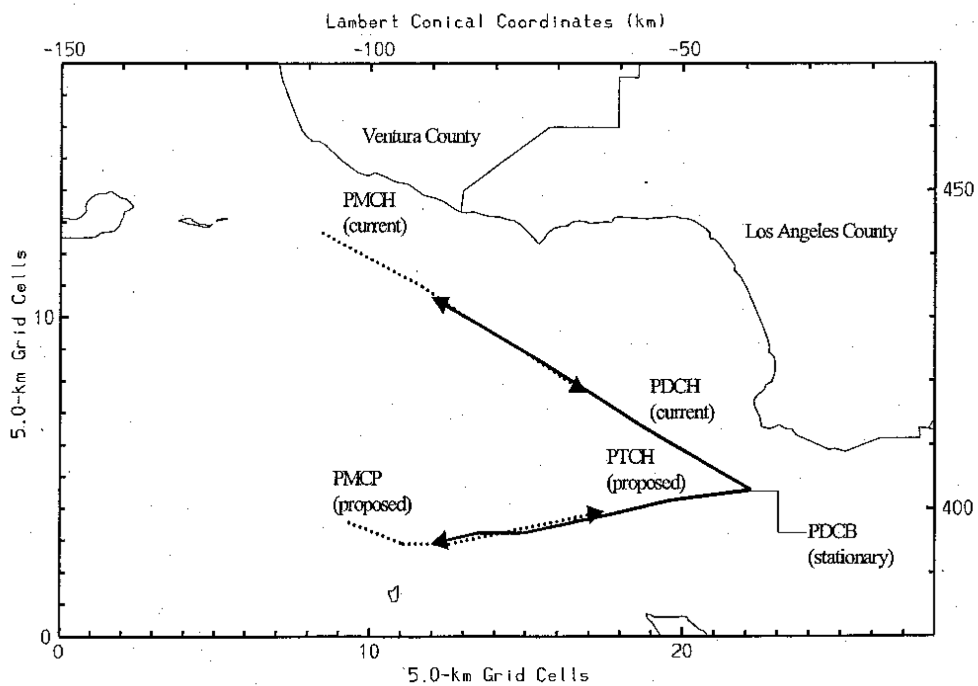
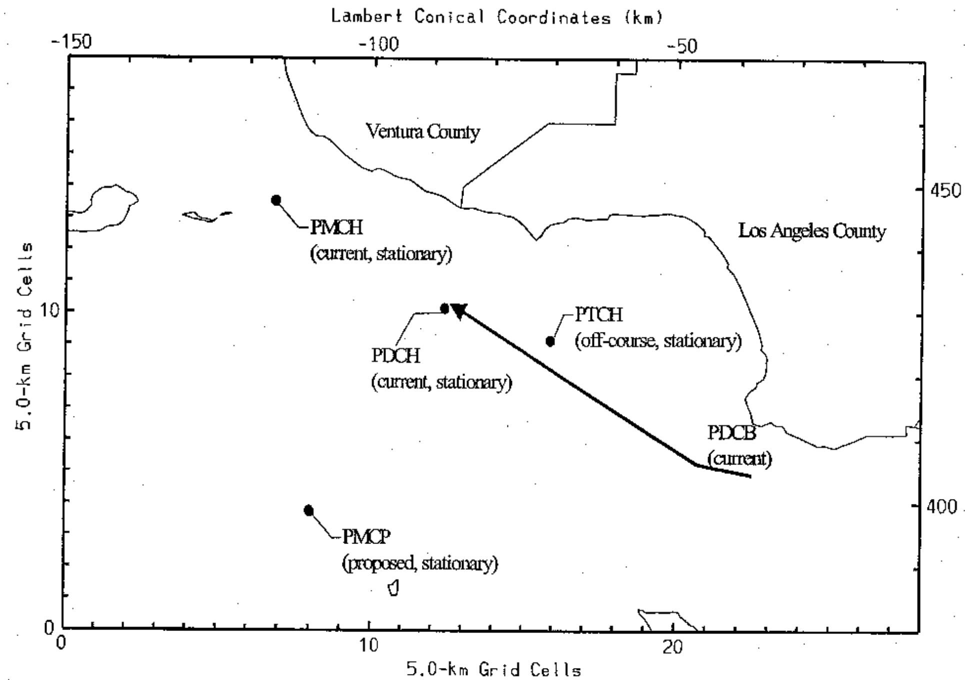


Figure IV-4
Tracers and Release Locations for Test #4



B. ANALYSIS OF TRACER DATA

Quality Assurance

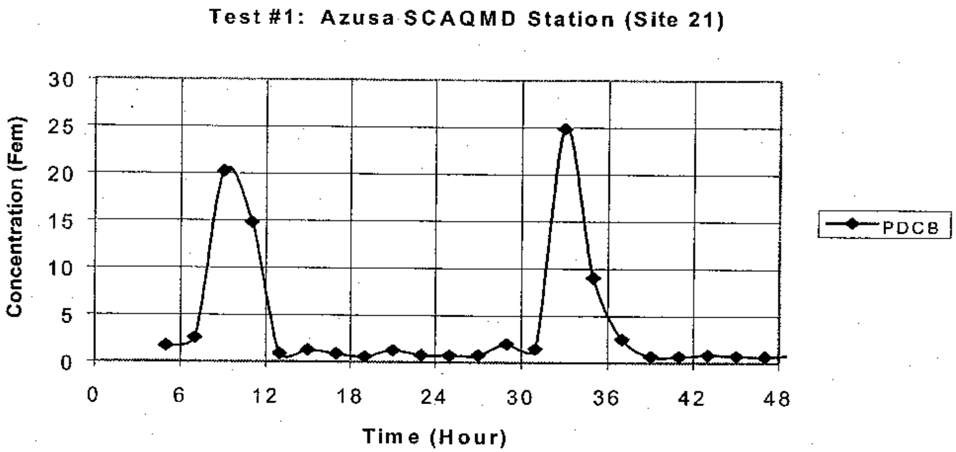
To ensure the overall quality of the tracer data, the ARB conducted an internal quality assurance (QA) review of the data sets containing the measured tracer concentrations. This analysis was an extension of the equipment and laboratory QA performed by the contractors.

BNL provided the tracer data in two Excel spreadsheets, one for the BATS data and the other for the CATS samplers. Each spreadsheet contained results for the three tracer tests. The BATS spreadsheet described the data set and contained the BATS data. The CATS spreadsheet contained the 24-hour average CATS data and the data from the two background tests. As part of their laboratory QA, BNL flagged as bad any data where: a) the tube was not used (last tube in lid or interim shutdown tube); b) the pump may have failed, the tube leaked badly, or the tube was plugged; or c) the sample was lost during analysis. The documentation provided by Brookhaven described analysis procedures, including procedures used to adjust the observed tracer concentrations to account for background concentrations and to identify bad or questionable data.

The data review conducted by the ARB consisted of two components: the first to review the data sets sent to the ARB by BNL to verify their completeness and clarity; the second was to review the data for outliers or otherwise questionable or non-representative data. It also included the preparation and analysis of time series and spatial plots of measured tracer concentrations. These analyses illustrated a number of artifacts in the tracer data sets not identified by Brookhaven. Significant tracer concentrations were measured prior to tracer release times and there were tracer concentrations that were much larger than at surrounding measurement sites. Many of these artifacts were identified by the ARB with flags in the data set to distinguish them as "questionable." Others were assumed to indicate significant background concentrations or interferences to the tracer measurement techniques. In addition, the methodology used by BNL to estimate concentrations above background resulted in some negative values; these values have been flagged to be treated as zero.

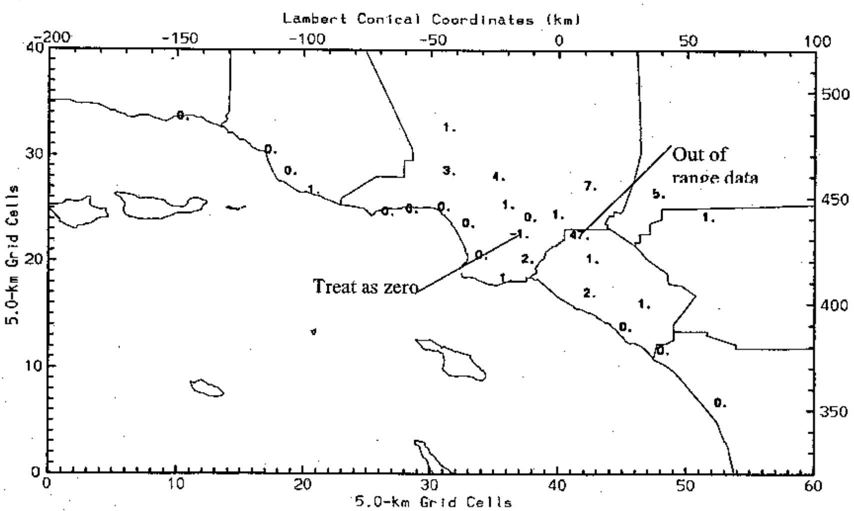
Three types of methods were used to check the tracer data: spatial plots, time series (temporal) plots, and inter-comparisons between the four co-located BATS and CATS samplers. The BATS data for each site were plotted temporally to check the diurnal consistency of the data. Figure IV-5 below shows an example of such a temporal plot.

Figure IV-5
Sample Temporal Plot



The data were also plotted spatially, to check for consistency with nearby sites. Figure IV-6 shows a sample spatial plot.

Figure IV-6
Sample Spatial Plot
(8/24/97 at 5 p.m. for PMCP)



Finally, the BATS and CATS data were inter-compared at the 4 co-located sites. The results of that comparison are shown in Tables IV-7 through IV-9.

Table IV-7
BATS vs. CATS Comparison for Tracer Test #1 (August 23, 1997)

Site	Date	PDCB		PMCP		PMCH		PDCH		PTCH	
		BATS	CATS	BATS	CATS	BATS	CATS	BATS	CATS	BATS	CATS
10	8/23	2.45	0.5	0.94	1.3	2.94	4	0.23	0.26	0.48	0
10	8/24	2.71	0.2	0.23	0.5	2.76	2.8	0.25	0	0.11	0
11	8/23	1.39	1.2	3.46	13.6	73.82	43.4	0.54	0.19	0.5	0.4
11	8/24	N/A	0.9	N/A	3.9	N/A	6.5	N/A	0	N/A	0.5
12	8/23	4.44	2.5	0.41	7.5	119.89	211.6	1.37	1.29	0.07	0
12	8/24	0.72	1.6	0.47	4.2	0.49	7.7	0.06	0.52	0.13	0.4
15	8/23	0.82	Bad	0.7	0	2.7	82.1	1.84	12.86	0.12	0.1
15	8/24	0.68	15.3	7.25	7.3	2.02	7	0.43	0	1.2	6.4

Table IV-8
BATS vs. CATS Comparison for Tracer Test #2 (September 4, 1997)

Site	Date	PDCB		PMCP		PMCH		PDCH		PTCH	
		BATS	CATS	BATS	CATS	BATS	CATS	BATS	CATS	BATS	CATS
10	8/23	N/A	0.3	N/A	0.9	N/A	3.4	N/A	0	N/A	0
10	8/24	0.86	0.5	0.54	3.3	2.5	4.1	0.19	0	0	45.8
11	8/23	2.11	0.4	16.39	11.7	2.67	3.2	0.23	0.83	0.77	9.4
11	8/24	1.06	1.6	10.65	10.6	2.68	10	0.2	0.79	0.19	0.6
12	8/23	0.46	1.8	0.37	25	154.6	126.4	0.05	1.05	0.05	3.3
12	8/24	11.35	8.1	9.44	8.3	4.11	23.4	0.5	0	0.72	0.7
15	8/23	0.62	1	0.47	0.7	34.56	40.1	0.51	0.44	0.11	0.8
15	8/24	0.83	N/A	10.55	N/A	1.98	N/A	0.07	N/A	0.19	N/A

Table IV-9
BATS vs. CATS Comparison for Tracer Test #4 (October 4, 1997)

Site	Date	PDCB		PMCP		PMCH		PDCH		PTCH	
		BATS	CATS	BATS	CATS	BATS	CATS	BATS	CATS	BATS	CATS
10	8/23	31.24	6	1.3	0	0.18	0.2	4.79	2.73	3.66	12
10	8/24	3.58	1.8	3.91	1.4	1.45	3.5	2.31	1.72	3.88	6.4
11	8/23	22.53	10	9.83	13.7	0.44	10.1	3.76	1.76	1.16	1.9
11	8/24	2.48	3	9.65	8.7	0.97	5.9	2.56	1.42	2.61	2.1
12	8/23	26.44	11.9	3.84	24.5	0.27	3.6	2.33	1.34	0.45	1.1
12	8/24	2.2	7.5	13.12	23.1	1.44	16.4	2.31	2.04	2.49	2.5
15	8/23	60.74	30.2	113.74	72.1	0.29	5.8	3.32	2.15	0.59	0.8
15	8/24	2.63	7	12.38	24.1	1.23	25.7	2.72	1.02	2.01	3.9

In most instances the two data samplers appear to track reasonably well, being relatively high or low at the same time. However, the concentrations do not agree consistently in magnitude or in which is higher. Because they are passive samplers, the CATS samplers are less reliable than their BATS counterparts, for which a known volume of air is pulled through the samplers. After discussions with Tracer ES&T regarding this issue, it was agreed that the CATS data should not be used for any of the subsequent technical analyses.

The final product of the QA process is a set of updated spreadsheets with appropriate flags included.

Normalization

As described previously, a series of three tracer tests were conducted to measure the atmospheric impacts from releases in the existing and proposed shipping lanes. The release configurations (amounts released and ship speeds) varied between the releases. Also, different tracer compounds were used in each test to represent the different shipping lane releases; these included a release from the point of separation, and morning and afternoon releases from each of the shipping lanes, as described previously. In order to account for these differences, the data were normalized. The results of the normalization allow a more direct comparison between similar time releases during an episode. Thus, for example, it is possible to directly compare differences in dispersion between the morning releases for the existing and proposed shipping lanes, and between the afternoon releases for each of the releases.

The data were normalized using a two-step procedure. First, the data for all three tracer tests were divided by the average mass of tracer released during the first two hours of each release, since the sampling resolution of the bulk of the BATS samplers was two hours. The few BATS samplers with one-hour resolution were converted to two-hour averages prior to this step. Table IV-10 summarizes the mass released during the first two hours for each of the tracers and episodes.

Table IV-10
Average Tracer Mass Released During First Two Hours (g/hr)

Tracer Test	Tracer				
	PDCB	PMCH	PMCP	PDCH	PTCH
August 23, 1997	1607.40	1310.04	880.20	1055.16	1169.64
September 4, 1997	470.00	730.00	1597.46	1620.00	1001.52
October 4, 1997	1642.68	1627.56	1595.16	1485.00	1474.92

After this step, daily station peaks were determined for all sites for the three tracer release days. The station peaks in Ventura County, San Diego County, and the SCAQMD were then separately averaged, to serve as an indicator of the extent of the tracer plume impacting each area. In order to avoid the inclusion of stations with no true peak, i.e., with background values, only stations with non-normalized tracer concentrations greater than 5 femtoliters/liter (fl/L) were included.

A second adjustment was then made to the station peak averages for the moving point source releases to account for differences in ship distance traveled during the first two hours of each release. In this step, ship- and test-specific adjustment factors were developed from each set of morning and afternoon releases for the August 23 and September 4 tracer tests. Factors were not developed for the October 4 tracer test because that test was comprised of predominantly stationary (non-moving) releases.

For the morning and afternoon of each test, ship-specific adjustment factors were calculated as follows:

$$K_1 = \frac{\overline{L}}{L_1} \quad ; \quad K_2 = \frac{\overline{L}}{L_2}$$

where K_1 = adjustment factor for the release vessel in the existing shipping lane

K_2 = adjustment factor for the release vessel in the proposed shipping lane

$\overline{L} = \frac{L_1 + L_2}{2}$ = average distance traveled by the release vessels in the existing and proposed lanes

L_1 = distance traveled during the first two hours of the release by the vessel in the existing shipping lane

L_2 = distance traveled during the first two hours of the release by the vessel in the proposed shipping lane

Table IV-11 shows the adjustment factors obtained using this methodology.

Table IV-11
Ship- and Test-Specific Adjustment Factors (K) for Distance Traveled

Tracer Test	Morning Releases		Afternoon Releases	
	Current Shipping Lanes (PMCH)	Proposed Shipping Lanes (PMCP)	Current Shipping Lanes (PDCH)	Proposed Shipping Lanes (PTCH)
August 23, 1997	0.8733	1.1697	1.0179	0.9828
September 4, 1997	0.9378	1.0711	0.9279	1.0843

It should be noted that the above normalization is a first order correction to boat speed which is valid only if the release vessel speeds are similar in magnitude.

As the final step in the normalization process, the average of the station peaks for each tracer compound was then divided by the adjustment factors above for the August 23 and September 4 tracer releases; no adjustments were made to the October 4 results as discussed above. The resulting data serve as the basis for direct comparisons between the two shipping lanes. Table IV-12 summarizes the results of the normalization process.

Table IV-12
Results of the Normalization Process: Average Normalized Station Peaks (fl/L)*,**

	Morning Releases				Afternoon Releases			
	Current Shipping Lanes (PDCH)		Proposed Shipping Lanes (PTCH)		Current Shipping Lanes (PMCH)		Proposed Shipping Lanes (PMCP)	
August 23, 1997	avg.	*# stations**	avg.	*# stations**	avg.	*# stations**	avg.	*# stations**
Ventura County	0	*(0)*	0	*(0)*	0	*(0)*	0	*(0)*
South Coast AQMD	0.26	*(10)*	0	*(0)*	3.47	*(11)*	6.20	*(10)*
San Diego County	0.27	*(1)*	0	*(0)*	0	*(0)*	2.07	*(1)*
September 4, 1997								
Ventura County	0	*(0)*	0	*(0)*	0	*(0)*	0.04	*(1)*
South Coast AQMD	9.99	*(5)*	3.99	*(7)*	5.21	*(13)*	1.07	*(11)*
San Diego County	0	*(0)*	1.60	*(1)*	0	*(0)*	0.07	*(1)*
October 4, 1997								
Ventura County	N/A	N/A	N/A	N/A	0	*(0)*	0	*(0)*
South Coast AQMD	N/A	N/A	N/A	N/A	1.36	*(2)*	1.35	*(17)*
San Diego County	N/A	N/A	N/A	N/A	0	*(0)*	0	*(0)*

* *Only station peaks corresponding to non-normalized concentrations > 5 fl/L were included during the averaging process to avoid including background values; the numbers in parentheses indicate the number of station peaks satisfying this criterion.*

** *The August 23 and September 4 tracer releases were adjusted to account for ship distance traveled; the October 4 release was not, because the release was stationary.*

As an aid to interpreting the results of the normalization process, ratios of the impacts (average normalized station peaks) from the proposed shipping lane to those in the current lane for the South Coast AQMD were developed for each of the comparable releases. These ratios are presented in Table IV-13.

Table IV-13
Ratios* of Proposed Shipping Lane Impact to Current Shipping Lane Impact in the South Coast AQMD

	Ratio for Morning release	Ratio for Afternoon Release
August 23, 1997	0	1.79
September 4, 1997	0.40	0.21
October 4, 1997	N/A	0.99

* *The ratio of average normalized station peak concentrations for the proposed lane to that from the current lane, from Table IV-12 above.*

As defined, ratios less than 1.0 in the above table imply greater dispersion from the proposed lane. Conversely, ratios greater than 1.0 imply less dispersion from the proposed lane. Ratios near 1.0 imply similar dispersion for the two lanes.

Tables IV-12 and IV-13 suggest the following qualitative conclusions from the tracer study:

- There is greater dispersion from the proposed shipping lane for some, but not all, of the tracer releases. For one release there was no discernable difference between the two lanes, and for another there was a disbenefit.
- The results strongly suggest that meteorology influences the direction and magnitude of dispersion benefits for the proposed shipping lane.

References

Tracer Environmental Sciences & Technologies, Inc. 1997a. Task 1 Deliverable for the Tracer Dispersion Study of Shipping Emissions During the 1997 Southern California Ozone Study: Review and Evaluation of Past Tracer Studies. June 24, 1997. Available from the South Coast Air Quality Management District.

Tracer Environmental Sciences & Technologies, Inc. 1997b. Task 4 Deliverable for the Tracer Dispersion Study of Shipping Emissions During the 1997 Southern California Ozone Study: Tracer Test Plan. August 26, 1997. Available from the South Coast Air Quality Management District.

Tracer Environmental Sciences & Technologies, Inc. 1998. Task 7 Deliverable for the Tracer Dispersion Study of Shipping Emissions During the 1997 Southern California Ozone Study: 1997 SCOS97 Tracer Study. July 31, 1998. Available from the South Coast Air Quality Management District.

V

MODELING ANALYSIS

In this Chapter we describe the air quality modeling analysis that was conducted to numerically assess the differences in onshore impacts from the various marine vessel alternatives. At the direction of the technical working group, the modeling analysis did not consider photochemistry.

A. METEOROLOGICAL MODEL

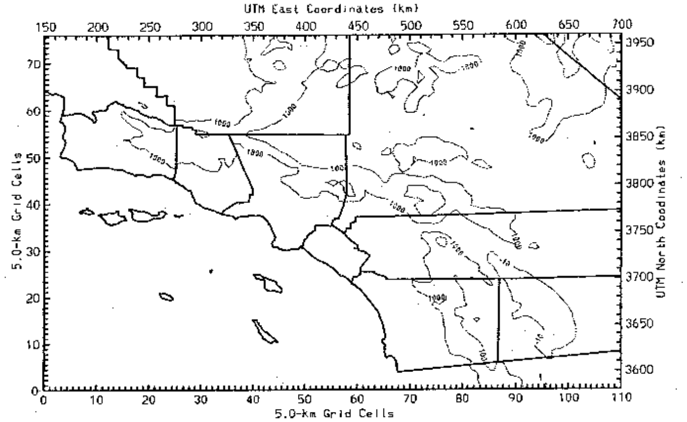
The meteorological fields were developed using CALMET, a diagnostic meteorological model (U.S. EPA, 1995). The CALMET model is based on objective analysis with diagnostic parameterizations to adjust the objective analysis results to account for non-divergence, terrain influences, and smoothing. It is limited in that the resulting parameter fields are only as good as the input observational data are representative, and important physical properties such as mass continuity are not ensured. However, CALMET is relatively easy to run and to manipulate its output to ensure idealized flow patterns. Care was taken to ensure that the model was exercised in a manner that would be appropriate for the region on any day, and not just the day of the tracer release.

The modeling domain was defined in a UTM coordinate system with 110 x 74 grid cells with a resolution of 5-km (Figure V-1). The domain coordinate system was defined as follows:

UTM Zone 11:	Easting:	150.0–700.0 km
	Northing:	3580.0–3950.0 km

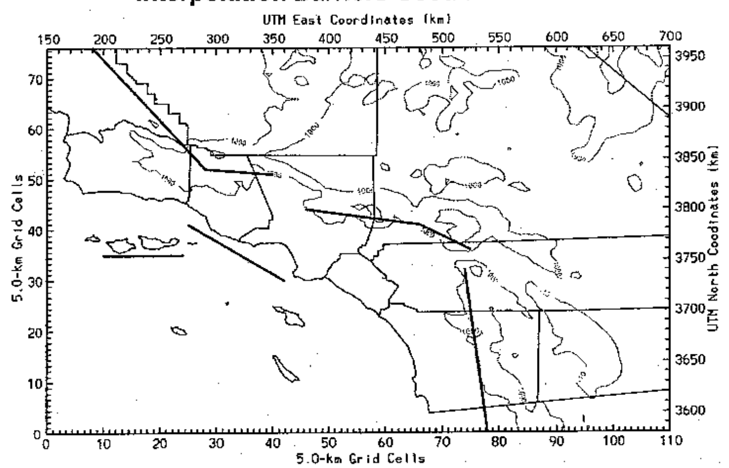
The vertical CALMET domain was defined using 16 layers to a height of 5000 meters above ground level.

Figure V-1
Air Quality Modeling Domain



Interpolation barriers were defined to limit offshore extrapolation from onshore wind monitoring sites, and to limit extrapolation from either side of the crests of various mountain ranges (see Figure V-2). Meteorological data collected during the SCOS97 were input to the model and used to generate three-dimensional meteorological fields for September 4-5, 1997.

Figure V-2
Interpolation Barriers Used in CALMET



B. WINDFIELD VALIDATION AND PEER REVIEW

In order to provide the best possible windfields for the simulated comparative analyses, a windfield validation component was included as an integral part of the windfield development process. In addition, peer review was provided by a group of meteorologists and air quality modelers with expertise in the southern California region. Participants in the peer review process included the U.S. Navy, Ventura County APCD, San Diego County APCD, Santa Barbara County APCD, South Coast AQMD, and the ARB. The group reviewed interim products and provided valuable suggestions for windfield improvement. Due to the compressed time frame for completing the technical work and unforeseen resources required to complete the tracer data analysis, the peer review group was not able to complete their peer review of the September 4-5 windfields. They did, however, reach consensus on the acceptability of windfields for August 3-7, a SCOS97 episode that is also available for simulating the onshore impacts of the marine vessel control strategy options.

In the remainder of this section we summarize the simulation of the September 4-5, 1997 tracer experiment using the CALGRID air quality model (Sigma Research Corp. 1989). The simulation results were compared with tracer concentrations observed onshore in southern California to validate the use of the air quality model for assessing the impact of offshore emissions. Subsequent to successful model validation, the model was applied to two episode periods to assess the relative impacts of shipping emissions from several shipping scenarios on southern California.

Tracer Emission Inventory

In this experiment, the tracers were released from moving and stationary point sources resolved to the minimum grid resolution for the model, which was 5 km. These emissions were constant for each 1-hour period.

To develop the tracer emission inventory for the air quality model, the position of each ship was calculated at 1-km intervals along the tracer release path. The time required for each 1-km traverse was calculated and the tracer released during that time period was also calculated, based on the average change in weight in the tracer canisters for that period. At each 1-km interval, the position of each ship was translated into the grid cell coordinate of the air quality modeling domain and the emissions were added to that grid cell in the gridded emission inventory. Because the emissions were prorated in each grid cell based on 1-km traverse intervals, and because each release path could not be exactly represented in 1-km increments, the mass of the simulated tracer emissions were close to, but did not exactly match the actual mass of tracer emissions (Table V-1).

Table V-1
Simulated and Measured Tracer Release Data for the September 4, 1997 Tracer Experiment

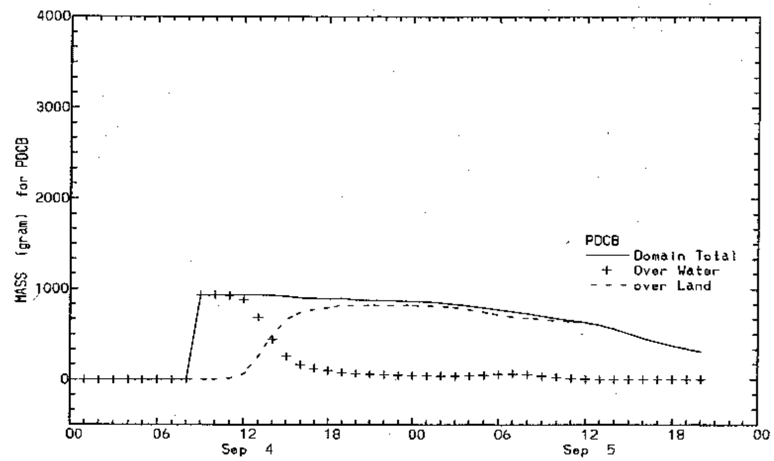
Shipping Lane	Release Type	Tracer	Measured Release Mass (g)	CALGRID Emitted Mass (g)
Both *(point of separation)*	Stationary	PDCB	940	935
Current *(morning, near shore)*	Moving	PDCH	3470	3500
Proposed *(morning, near shore)*	Moving	PTCH	2800	2766
Current *(afternoon, offshore)*	Moving	PMCH	2350	2354
Proposed *(afternoon, offshore)*	Moving	PMCP	2990	3000

Simulations

The CALMET meteorological fields and the emission inventory prepared from the September 4, 1997 tracer experiment were used as inputs to the CALGRID air quality model. The CALGRID domain was identical to the CALMET domain (110x74x16 cells). Since the tracer chemical species are inert, the model was run with photochemistry disabled. The CALGRID model was run for the period September 4, 0200 PDT to September 5, 2300 PDT and generated 3-dimensional, hourly concentrations of each tracer.

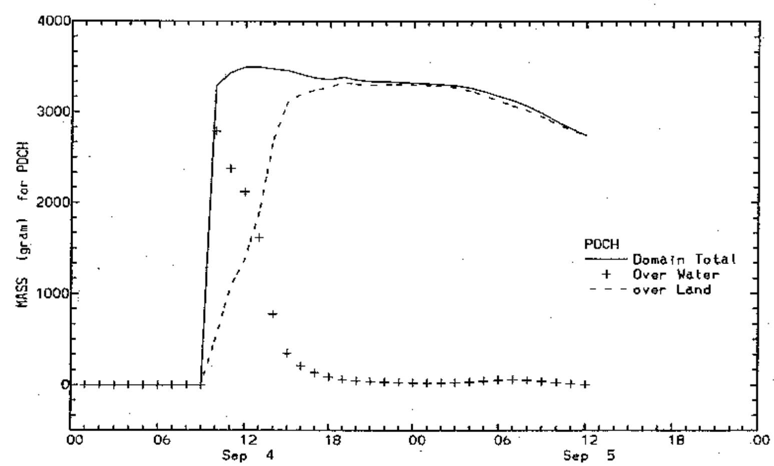
As a check on the integrity of the simulation results, the total mass of each tracer within the modeling domain was calculated hourly, as well as the total mass over water and the total mass over land. These results show that after 24 hours from the end of the tracer release periods, at least 90% of the mass of each tracer is still within the modeling domain (Figures V-3 through V-7). The decline in total mass after 24 hours was attributed to mass leaving the modeling domain at the domain boundaries.

Figure V-3
Total, Overwater, and Overland Mass of PDCB in the CALGRID Modeling Domain
(PDCB released from point of separation in the morning)



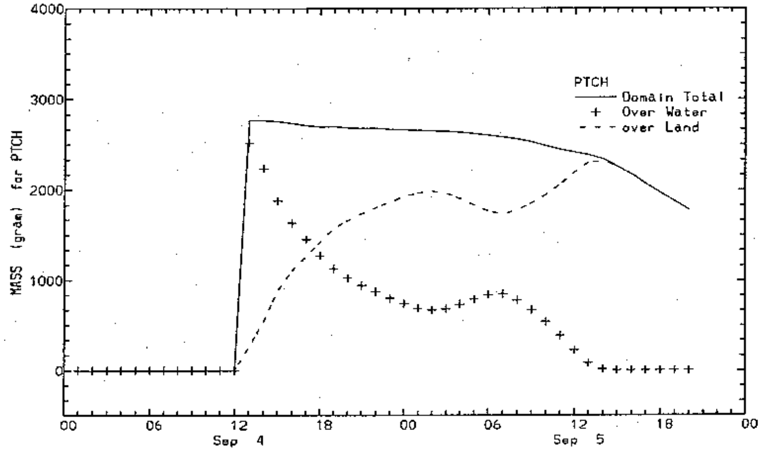
SCOS September 4 -- PDCB Mass in CALGRID

Figure V-4
Total, Overwater, and Overland Mass of PDCH in the CALGRID Modeling Domain
(PDCH released from current shipping lane in the morning)



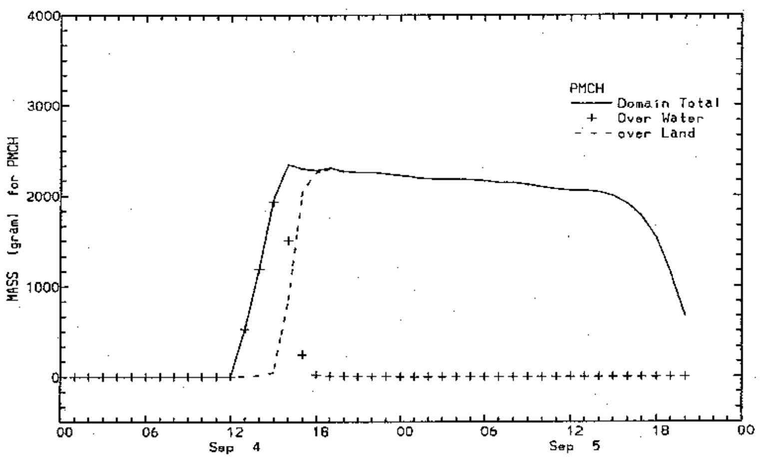
SCOS September 4 -- PDCH Mass in CALGRID

Figure V-5
Total, Overwater, and Overland Mass of PTCH in the CALGRID Modeling Domain
(PTCH released from proposed shipping lane in the morning)



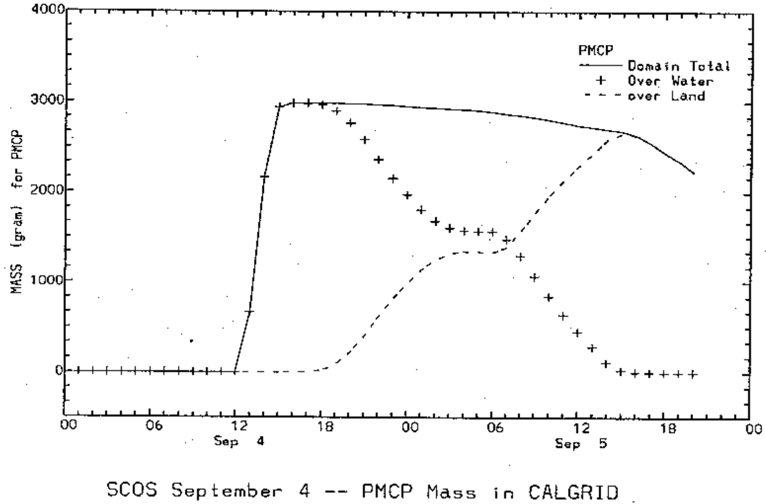
SCOS September 4 -- PTCH Mass in CALGRID

Figure V-6
Total, Overwater, and Overland Mass of PMCH in the CALGRID Modeling Domain.
(PMCH released from current shipping lane in the early afternoon)



SCOS September 4 -- PMCH Mass in CALGRID

Figure V-7
Total, Overwater, and Overland Mass of PMCP in the CALGRID Modeling Domain.
(PMCP released from proposed shipping lane in the early afternoon)



Windfield Validation

Windfield validation is actually a validation of the modeling system, which includes as components a meteorological model, an emissions model, and an air quality model. The objective of this validation analysis was to compare the results from the tracer experiment with the results from the simulated tracer experiment to ensure that the modeling system adequately represented the tracer experiment and, by inference, the behavior of air pollutants within the modeling domain.

One direct measure of the impact of offshore emissions on onshore air quality is the accumulated mass flux and its distribution along the shoreline of southern California resulting from the offshore emissions. Mass flux calculations can be made from the simulation results. However, mass flux calculations from the observational data are more problematic. The observations are ground level only, and the vertical extent of the observed concentrations is unknown. Also, there were large areas of the study domain, including those portions over water and those in the inland deserts, in which there were limited or no tracer concentration measurements. Thus, to estimate the impact of offshore emissions from the observational data requires relative, rather than absolute comparisons.

- ***Mass Fluxes from Simulation Results***

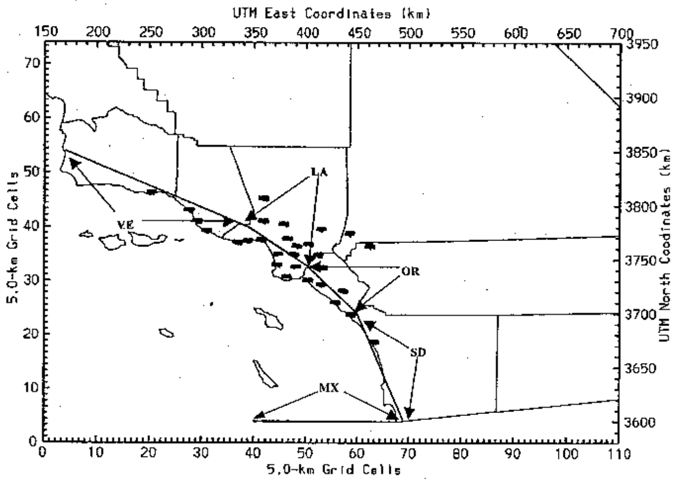
To calculate onshore mass fluxes from the offshore tracer releases, a series of line segments were defined for Ventura County (VE), Los Angeles County (LA), Orange County (OR), San Diego County (SD), and the southern boundary of the California Bight (MX) (see Figure V-8). By post-processing the CALGRID simulation results, the hourly mass flux across each of these line segments was calculated from the surface to a height of 2000 meters above ground level, using the following relationship:

$$FLUX = (WSPD) * \cos(WDIR - ANGLE)$$
$$* CONC * WMOL * SAREA * MDEN$$

where
FLUX = mass flux (gm/hour),
WSPD = wind speed (m/sec),
WDIR = wind direction,
CONC = tracer concentration (volume %)
ANGLE = the orientation angle for each line segment,
WMOL = tracer molecular weight (gm/gm-mole),
SAREA = cross-sectional area of each grid cell (m^2), and
MDEN = molecular density (gm-mole/m^3) corrected to ambient temperature and pressure.

This mass flux calculation was only an approximation of the actual mass fluxes calculated within the CALGRID model. Within the model, mass fluxes are calculated at intervals of between 5 and 10 minutes using equations that are non-linear and concentration gradients interpolated over a number of grid cells. However, the tracer concentrations output by the model at 1-hour intervals represent only the most recent time step. The average hourly concentrations can only be estimated. Also, the above flux calculation accounts for advective fluxes only. Diffusive fluxes within the model may also have been important in the determination of mass distribution, especially where concentration gradients were large and wind speeds were low.

Figure V-8
Line Segments Used to Calculate Mass Flux for Ventura (VE), Los Angeles (LA), Orange (OR), and San Diego (SD) Counties, and the Southern End of the California Bight (MX) (Markers denote tracer sampling sites.)



The simulated, hourly net mass fluxes across the vertical planes represented by each of the line segments were accumulated for the period September 4, 0200 PDT through September 5, 2300 PDT. The results of these calculations (Tables V-2 and V-3) show that simulated flows advected through all line segments accounted for between 90% (PMCP) and 107% (PMCH) of the mass from the tracer releases. Only small mass fractions of any of the tracers passed through the line segments represented by Ventura County or the California Bight.

The 107% mass of PMCH accounts for slightly more mass than was released during the tracer experiment. Also, the 90% of the PMCP mass in the flow calculations suggests that not all of the PMCP mass was accounted for by the model. Eulerian models have been known to create or remove mass because of characteristics of the numerical methods used. However, mass calculations for the domain (see Figures V-3 through V-7) show that 95% or more of the mass of each tracer was conserved within the modeling domain well after the release period, and until the tracers reached the domain boundaries. Therefore, these apparent discrepancies in the accumulated mass fluxes were attributed to the approximate nature of the mass flow calculations. Because most (90% to 107%) of the mass was accounted for in the calculations, and since the total mass within the modeling domain was largely conserved, it was concluded that the simulated relative distribution of mass flux for each tracer was a reasonable approximation of the observed distribution.

Table V-2
Distribution of Simulated, Accumulated Net Tracer Mass Fluxes (grams) Among the Defined Line Segments
(Numbers in parentheses represent percentage of total)

Shipping Lane	Tracer	VE	LA	OR	SD	MX	Total
Both *(point of separation)*	PDCB	4 (0%)	8 (1%)	745 (81%)	137 (15%)	21 (2%)	915
Current *(morning, near shore)*	PDCH	0 (0%)	308 (9%)	2949 (89%)	60 (2%)	1 (0%)	3318
Proposed *(morning, near shore)*	PTCH	13 (0%)	181 (7%)	2159 (79%)	333 (12%)	63 (2%)	2749
Current *(afternoon, offshore)*	PMCH	16 (1%)	2102 (84%)	391 (16%)	0 (0%)	0 (0%)	2509
Proposed *(afternoon, offshore)*	PMCP	64 (2%)	1054 (39%)	1351 (50%)	199 (7%)	32 (1%)	2700

Table V-3
Percentage of Emitted Tracer Mass Accounted for by Mass Fluxes Through Onshore Line Segments Calculated from Simulation Results

Shipping Lane	Tracer	Simulated Mass (g)	Released Mass (g)	Fraction (%)
Both *(point of separation)*	PDCB	915	940	98
Current *(morning, near shore)*	PDCH	3318	3470	96
Proposed *(morning, near shore)*	PTCH	2749	2800	99
Current *(afternoon, offshore)*	PMCH	2509	2350	107
Proposed *(afternoon, offshore)*	PMCP	2700	2990	90

- ***Mass Fluxes from Observations***

The calculation of mass fluxes from observations at surface monitoring sites required a number of assumptions. The horizontal and spatial representativeness of the concentrations observed at each site was unknown. Also, horizontal gradients can only be inferred from concentrations at surrounding sites based on the assumption that the spatial resolution of the monitoring network is smaller than the spatial scale of the cross section of the plume being sampled. The current and proposed offshore shipping lane release points were on a scale of 100 km upwind of Orange County where the highest concentrations of the tracers released were observed. Based on Pasquill's diffusion curves for neutral conditions, at 100 km distance, the cross-sectional width of a point source plume would be approximately 10 km (USAEC,1968). The near shore (morning) tracer releases were even closer to the shoreline, with correspondingly narrower plumes. Therefore, there is uncertainty associated with estimating mass fluxes based on the tracer sampling network.

For this analysis, the horizontal distribution of each tracer concentration was determined using a distance-weighted ($1/r^2$) interpolation from the sampling sites. Each site had a maximum radius of influence of 15 km and elsewhere within the domain the concentrations were assumed to be zero. Tracer concentrations of 5 femtoliters/liter or less were assumed to be zero (to account for background). Such an interpolation would work poorly in those areas of the domain with few, or no monitoring sites; however, the concentrations were needed in this analysis only along the line segments which is where most of the monitoring sites were located. The vertical distribution of tracer concentrations was estimated by assuming constant values within the mixed layer as defined by the CALMET meteorological fields. Using these assumptions, the hourly concentration distribution of each tracer within the vertical plane defined by each line segment was calculated.

The mass flux based on the observations of each tracer, across each line segment, was calculated in the same manner as for the simulated flows. The concentrations defined for the vertical plane represented by each line segment were mapped into the CALGRID modeling domain and the CALMET wind speed and direction fields were used to calculate hourly mass flows. Accumulated mass fluxes for the period September 4, 0200 PDT through September 5, 2300 PDT were calculated (Tables V-4 and V-5). The resulting calculated mass fluxes accounted for only a small fraction of the total mass of each tracer released. The accumulated mass flows ranged between 2.0% of the released mass for PDCB to 10.3% of the released mass for PTCH.

There are many uncertainties in the assumptions on which these calculations are based and it is difficult to select just one as the cause of these low percentages. Given the spatial scale of the monitoring network and the spatial scale of the tracer plumes estimated from the Pasquill diffusion curves, actual peak tracer concentrations may have been much higher than those observed, which would have translated into much higher calculated mass flows. However, any assumption of total tracer mass distribution would necessarily be proportional to the observed concentrations. Therefore, it was concluded that the relative mass flux distribution was represented by these calculations, even though the total mass resulting from these calculations was low.

Table V-4
Distribution of Accumulated Tracer Mass Fluxes (grams) Among the Line Segments Based on Analysis of Observed Concentrations
(Numbers in parentheses represent percentage of total)

Shipping Lane	Tracer	VE	LA	OR	SD	MX	Total
Both *(point of separation)*	PDCB	0 (0%)	0 (0%)	19.1 (100%)	0 (0%)	N/A	19.1
Current *(morning, near shore)*	PDCH	0 (0%)	0 (0%)	149.0 (100%)	0 (0%)	N/A	149.0
Proposed *(morning, near shore)*	PTCH	0 (0%)	0 (0%)	249.2 (86%)	39.1 (14%)	N/A	288.3
Current *(afternoon, offshore)*	PMCH	0 (0%)	12.6 (7%)	169.8 (93)	0 (0%)	N/A	182.4
Proposed *(afternoon, offshore)*	PMCP	0 (0%)	25.8 (15%)	111.2 (64%)	36.4 (21%)	N/A	173.4

Table V-5
Percentage of Emitted Tracer Mass Accounted for by the Observed Tracer Concentrations Along Onshore Line Segments

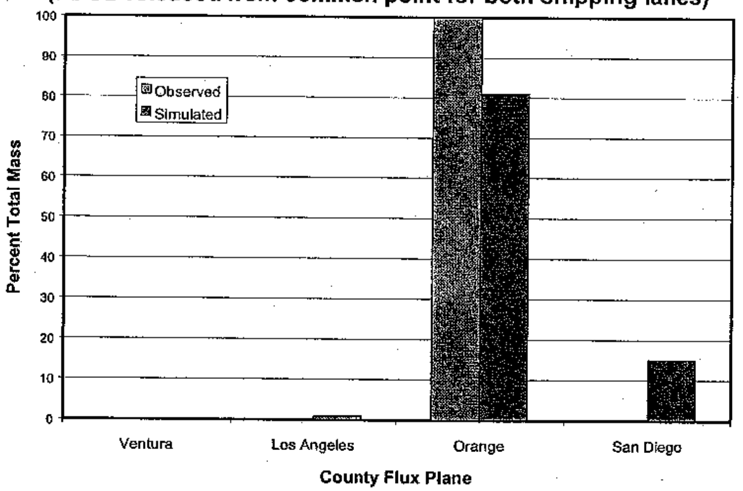
Shipping Lane	Tracer	Simulated Mass (g)	Released Mass (g)	Mass Fraction (%)
Both *(point of separation)*	PDCB	19.1	940	2.0
Current *(morning, near shore)*	PDCH	149.0	3470	4.3
Proposed *(morning, near shore)*	PTCH	288.3	2800	10.3
Current *(afternoon, offshore)*	PMCH	182.4	2350	7.8
Proposed *(afternoon, offshore)*	PMCP	173.4	2990	5.8

- ***Comparison of Simulated and Observed Mass Fluxes***

Given the low mass percentages calculated from the observed tracer concentrations, *direct* comparisons between the mass flux results from the simulations and from the observations are not appropriate. However, *relative* comparisons were made, to take advantage of the particular strength of grid-based models to estimate relative changes between strategies. Based on the CALGRID result that virtually all of the tracer mass comes onshore, it is a reasonable assumption to accept the relative distribution of tracer mass fluxes, even if the total mass cannot be accounted for in these calculations. This is because any revised estimate of mass flux would be proportional to the observed concentrations, i.e., the percentages captured would change but the relative distribution would not. Thus the relative mass fluxes can be compared to those calculated from the CALGRID simulation results.

Using the results from Tables V-2 and V-4, the percentages of the total mass flux passing through the vertical planes represented by Ventura, Los Angeles, Orange, and San Diego Counties were calculated. Comparisons between the percentages calculated from the observations and from the simulation results are shown for each tracer in Figures V-9 through V-13.

Figure V-9
Comparison of Accumulated PDCB Mass for Ventura, Los Angeles, Orange, and San Diego County Line Segments Using CALGRID Results and Tracer Measurements
(PDCB released from common point for both shipping lanes)



The tracer PDCB was released from the common, or separation, point of the current and proposed shipping lanes. Based on the observations, all of the tracer came onshore within the Orange County line segment. Based on simulation results, 81% came onshore within the Orange County line segment, and 15% came onshore within the San Diego line segment (Figure V-9).

Figure V-10
Comparison of Accumulated PDCH Mass for Ventura, Los Angeles, Orange, and San Diego County Line Segments Using CALGRID Results and Tracer Measurements
(PDCH released from current shipping lane in the morning)

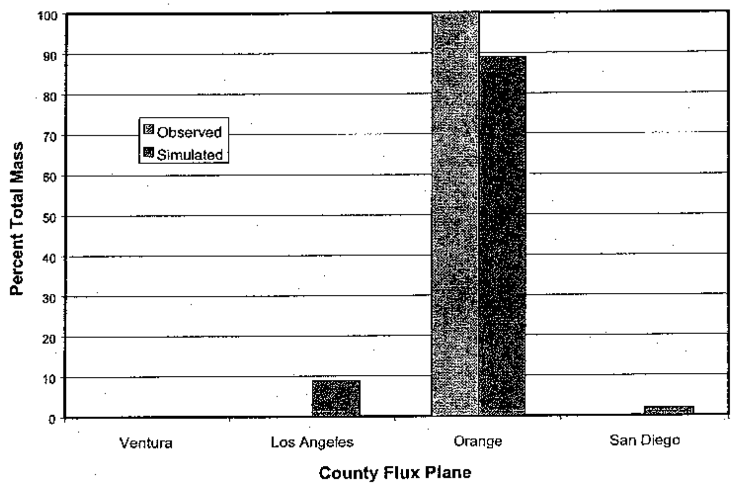
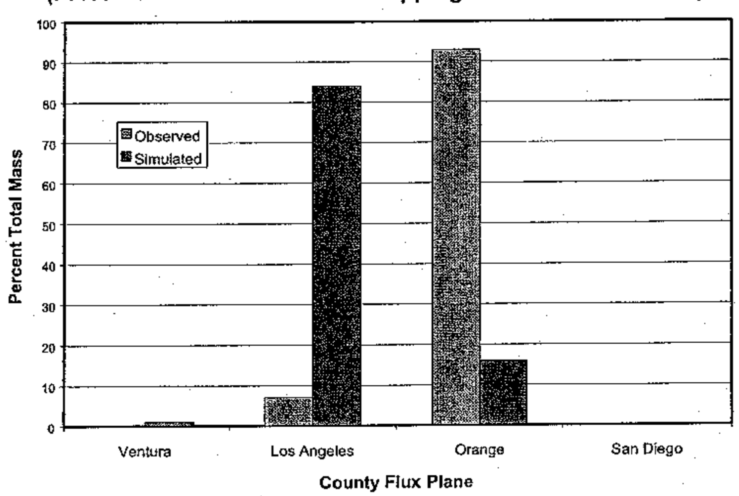


Figure V-11
Comparison of Accumulated PMCH Mass for Ventura, Los Angeles, Orange, and San Diego County Line Segments Using CALGRID Results and Tracer Measurements
(PMCH released from current shipping lane in the afternoon)



The current shipping lane was represented by two tracer releases, PDCH (morning, outbound) and PMCH (afternoon, inbound). Based on the observations, all of the PDCH tracer mass came onshore within the Orange County line segment. Based on the simulation results, 89% of the mass came onshore within the Orange County line segment, with most of the remaining 11% within in the Los Angeles County line segment (Figure V-10). For PMCH (Figure V-11), 93% of the observation-based mass came onshore within the Orange County line segment and 7% within the Los Angeles County segment, while from the simulation results only 16% came onshore within the Orange County line segment and 84% came onshore within the Los Angeles County line segment. This discrepancy is discussed further below.

Figure V-12
Comparison of Accumulated PTCH Mass for Ventura, Los Angeles, Orange, and San Diego County Line Segments Using CALGRID Results and Tracer Measurements
(PTCH released from proposed shipping lane in the morning)

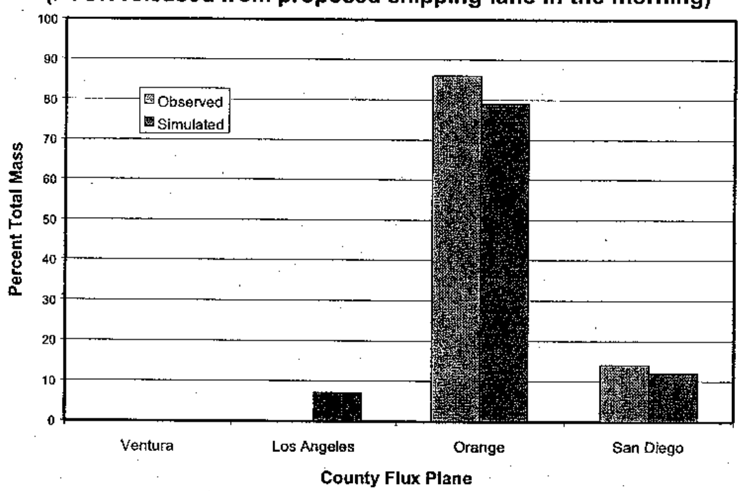
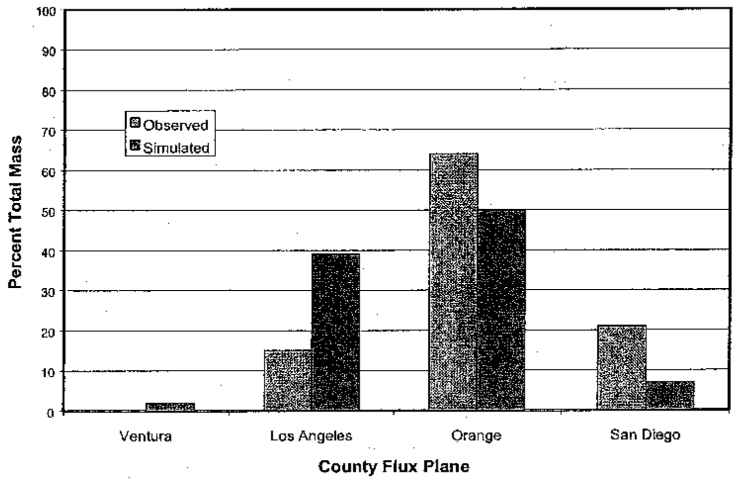


Figure V-13
Comparison of Accumulated PMCP Mass for Ventura, Los Angeles, Orange, and San Diego County Line Segments Using CALGRID Results and Tracer Measurements
(PMCP released from proposed shipping lane in the afternoon)



The proposed shipping lane was also represented by two tracers, PTCH (morning) and PMCP (afternoon). Based on the observations, 86% of the PTCH mass came onshore within the Orange County line segment, while for the simulation results 79% came onshore within the Orange County line segment (Figure V-12). For PMCP (Figure V-13), the observed onshore mass flux was distributed among the Los Angeles, Orange, and San Diego line segments, with 64% of the mass flux through the Orange County line segment and the remainder divided between the Los Angeles and San Diego County line segments. Based on the simulation results, the mass flux was also distributed among the same three line segments, with 50% of the mass flux within the Orange County line segment.

With the exception of PMCH, the relative mass flux distributions calculated from the simulation results are in general agreement with those calculated using the observations. The simulation results tend to be more widely distributed, which can be attributed to the numerical diffusion characteristic of Eulerian models. The largest discrepancy among the mass flux distributions (Figure V-11) is for PMCH, in which observations indicated that most of the mass came onshore in Orange County and the simulation results indicated a larger proportion in Los Angeles County. This discrepancy can be attributed to the wind flow patterns offshore in Santa Monica Bay. In this part of the domain, wind flow patterns are complex but are poorly represented by observations. However, both Los Angeles and Orange Counties are within the South Coast Air Basin, which is the focus of the current study. Since the onshore impact in the South Coast Air Basin is of concern, the observed and simulated mass flow distributions are in reasonable agreement.

The results from this comparison of simulated and observed mass flux distributions should be interpreted with care. In general, the simulated mass fluxes were more widely distributed than those based on observations. This was not surprising given the known tendency of Eulerian models for numerical diffusion. However, the simulation results better represent the 3-dimensions of the physical domain than do the observations. The greater distribution of the simulated tracers can be partially attributed to vertical wind shear that dispersed the tracers in a manner not detectable in ground-level observations. Also, the density of the sampling network was much less in Ventura and San Diego Counties than for Los Angeles and Orange Counties. Therefore, there was a much greater uncertainty in the mass distributions calculated from observed tracer concentrations in Ventura and San Diego Counties.

- ***Tracer Dilution Ratios (X/Q)***

The tracer dilution ratio (denoted X/Q) is a standard metric for assessing relative impacts in atmospheric tracer studies. The X/Q value is a ratio of tracer concentration within a sampling network to the tracer emission rate (units are hour/m^3). It represents a normalized index of tracer concentration to allow comparisons between different tracer experiments, release points, or different time periods during the same study.

In this analysis, peak X/Q values were calculated using the observed tracer concentrations and using the simulation results from the air quality model. The two sets of X/Q values were then compared with the objective of testing whether the pattern of X/Q values from the observations was adequately represented by those from the simulation results. The interpretation of either set of X/Q values was not an objective of this analysis. The goal was to validate the reliability of the air quality modeling system.

- ***X/Q from Observed Concentrations***

Ideally, X/Q values represent the peak plume concentrations of a tracer. In practice, however, the tracer-experiment sampling networks rarely have sufficient spatial density to measure actual peak concentrations with confidence. For example, Gaussian dispersion of the plume of a tracer released 100 km offshore could have a plume width of less than 10 km when it reached the shore (USAEC, 1968), which is approximately the width of the tracer sampling network used in the 1997 experiments. Wind speed, wind direction, the orientation of the tracer release path relative to the wind direction, and the ship movement could increase the width of the tracer plume. However, most of the tracers in this study were released much closer to the shoreline than 100 km, with plumes that were correspondingly narrower. Therefore, care must be used in interpreting X/Q values from observations.

The X/Q values were calculated using the maximum, 2-hour concentration of each tracer observed during the experimental period (most of the samplers measured concentrations averaged for 2 hours). These maximum concentrations were selected without consideration of the time or location of occurrence and are summarized in Table

V-6. Except for the PMCH tracer, the peak concentrations were measured in Orange County. The observed concentrations ranged from 9.84 to 64.45 x 10^{-9} gm/m^3.

Table V-6
Observed and Simulated Peak 2-hour Tracer Concentrations (gm/m^3 x 10^{-9}) for September 4 (County where peak occurred also shown)

Tracer	Observed		Simulated	
	Concentration	Location	Concentration	Location
PDCB	9.84	Orange	2.24	Orange
PDCH	64.45	Orange	39.70	Orange
PTCH	12.68	Orange	4.02	Orange
PMCH	13.01	Los Angeles	7.60	Los Angeles
PMCP	14.42	Orange	9.62	Orange

The tracer release periods for the September 4-5, 1997 experiment ranged from approximately 1.5 to 3 hours. The experimental plan called for the tracers to be released at a continuous rate throughout each of the release periods. In practice, however, the tracer emission rates varied markedly. Also, while the release periods varied in length, the observed tracer concentrations represented 2-hour averages. Therefore, for consistency between the tracer emissions and the observed concentrations, the emission rates used in the X/Q calculations were determined from the average emissions within the first 2 hours of each release period (see Table V-7).

Table V-7
Observed and Simulated X/Q (hour/m^3 x 10^{-12}) for September 4.*

Tracer	Emission Rate (g/hr)	Observed X/Q	Simulated X/Q
PDCB	470	20.9	4.8
PDCH	1600	39.8	24.5
PTCH	1000	12.7	4.0
PMCH	730	17.8	10.4
PMCP	1620	9.0	6.0

***The X/Q values are based on 2-hour average concentrations. The tracer emission rates are 2-hour averages, from the beginning of each release**

- ***X/Q from Simulation Results***

There are a number of characteristics of air quality models that influence how well simulation results represent observations. In this analysis, tracer concentrations output by the model were average concentrations for a 3-dimensional volume with a cross sectional area of 5x5 km^2 and a (surface-layer) height of 20 m (for the SCOS97 modeling domain). The observed tracer concentrations, however, represented a linear (2-hour) average at a single point. With an Eulerian model, the location of a plume of tracer concentrations can only be determined on a spatial scale commensurate with the grid resolution (5 km for this study). Also, numerical diffusion in Eulerian models tends to spread plume concentrations, thereby reducing the peak concentrations.

For this analysis, the simulated tracer concentrations used for the X/Q calculations were taken as the maximum 2-hour, onshore concentration of each tracer. The maximum simulated concentrations for each tracer ranged from 2.24 to 39.70×10^{-9} gm/m^3 (Table V-6). The maximum concentrations occurred on September 4, and represented the location at which each simulated plume reached the shoreline. Because of uncertainties in the wind fields, the time and location of maximum simulated concentrations did not exactly match those of the observations. However, for each of the 5 tracers, the county in which the simulated peak tracer concentrations occurred corresponded to that of the peak observed concentrations.

- ***Observed vs. Simulated X/Q***

In general, the simulated peak 2-hour tracer concentrations (and corresponding values of X/Q) were lower than the observed concentrations. The differences ranged from a factor of 4.4 for PDCB (e.g., 9.84 vs. 2.24×10^{-9} hour/m^3), to a factor of approximately 1.5 for PMCP (Table V-6). These differences were attributed to the 3-dimensional volume and the spatial scales represented by the simulation results.

To the extent that the X/Q values represented the relative onshore impact from the various tracer releases, the agreement between the X/Q values based on the observations and those based on the simulation results is less important than how well the differences among the tracer releases are represented. Relative X/Q values were calculated by dividing each of the X/Q values from the simulation results by the maximum X/Q among the 5 tracers released. For example, since the highest simulated value of X/Q was 24.5×10^{-12} hour/m^3 (PDCH), the resultant relative X/Q was 100%. Similar calculations were made using the observations and the resulting observed X/Q and simulated X/Qs are compared in Figure V-14.

Figure V-14
Relative X/Q for the September 4, 1997 Tracer Release

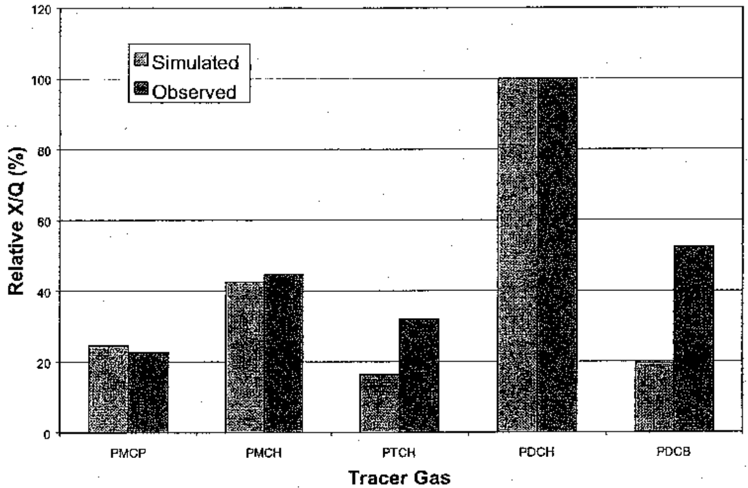


Figure V-14. shows general agreement between the relative X/Q values calculated from the observations and those calculated from the simulation results. The tracer emissions of PDCH (current lane, morning release) had the greatest relative impact in both the simulated and observed calculations. The X/Q for PTCH (proposed lane, morning release) indicates a reduced impact from PDCH of a factor of 4 based on the observed X/Q calculations and a factor of approximately 5 based on the simulated X/Q calculations. Both the observed and simulated X/Q calculations indicate a greater impact from PMCH (current lane, afternoon release) than from PMCP (proposed lane, afternoon release). The PDCB tracer represents the common point between the existing and offshore shipping lanes.

- ***Conclusions from Windfield Validation***

The comparison between observed concentrations from the tracer experiment on September 4, 1997 and simulation results using the CALMET meteorological model and the CALGRID air quality model used two analysis approaches. The first compared the relative distribution of mass from tracers released offshore through vertical planes defined from line segments representing each of Ventura, Los Angeles, Orange, and San Diego Counties. Based on this analysis, the modeling system placed 72% of the mass within the correct line segments as represented by the observation data. The second analysis approach compared observed and simulated tracer distribution ratios (X/Q). This analysis showed that the relative impact of the 5 tracer releases calculated from the simulation results were in general agreement with those calculated from the observed tracer concentrations.

C. MODELING ANALYSIS OF POTENTIAL MARINE VESSEL CONTROL STRATEGIES

As previously discussed, to mitigate the impact of emissions from offshore shipping on air quality in the SCAB, a number of marine vessel control strategies have been proposed. The proposed strategies include voluntary ship speed reductions and an alternative shipping lane. However, assessing the relative benefits of each of these strategies is difficult due to the day-to-day variations in ship traffic, changes in ship locations and emissions resulting from each of these strategies, and the complex wind flow patterns found within the California Bight. The approach used in this analysis for assessing the relative value of each strategy was to apply an Eulerian air quality modeling system to simulate the shipping lane and speed scenarios representing each of the strategies. From these modeling results, the mass of emissions from each of these scenarios impacting the SCAB was calculated. These calculations were used to assess the impact of each alternative lane and speed strategy.

SCOS97 was implemented to collect a meteorological and air quality data set suitable for modeling high ozone episodes in southern California. A field study was conducted during the period of July 15, through October 31, 1997 and included surface and aloft measurements to supplement the existing network of meteorological and air quality monitors. The result of this study was an extensive archive of aerometric data for 13 high-ozone episode days throughout the study period. As part of SCOS97, three experiments were conducted in which inert tracers were released from locations in the existing and proposed shipping lanes. Tracer concentrations were monitored along the coast of southern California from Santa Barbara County to San Diego County. The data from these tracer experiments provided a database suitable for validating a modeling system (described previously), and were subsequently used to assess the relative impacts of proposed marine vessel control scenarios.

To take advantage of the SCOS97 data sets, two episode periods from the study were selected for analysis of the alternative shipping lane and speed control scenarios. The period August 4-7, 1997 included the highest ozone concentrations observed in the SCAB during the study period. The period September 4-5, 1997 included a tracer experiment with results suitable for validating a modeling system. The validation of the modeling system was described previously. In the following analysis, emissions of nitrogen oxides (NO_x) from offshore shipping for each of the five lane and speed scenarios were simulated using an Eulerian air quality model. For each scenario, the net onshore mass flux into the SCAB was calculated. Comparisons of mass flux among the scenarios were made for each day of the two episodes simulated.

<u>Air Quality Modeling Procedures.</u>

For this analysis, the modeling system selected was comprised of the CALMET meteorological model and the CALGRID air quality model (described previously). The CALGRID simulations were begun at 0000 PDT on the day prior to the episode periods of interest. At the beginning of each simulation period, the initial concentration of NO_x

was assumed to be near zero (1.0×10^{-12} ppm) throughout the modeling domain. The extra day was needed to generate a suitable distribution of NO_x at the beginning of each episode period. Thus, the simulation periods were August 3-7, and September 3-5, 1997. The CALGRID model was run with the photochemical mechanism disabled and there were no NO_x emissions within the domain not related to offshore shipping.

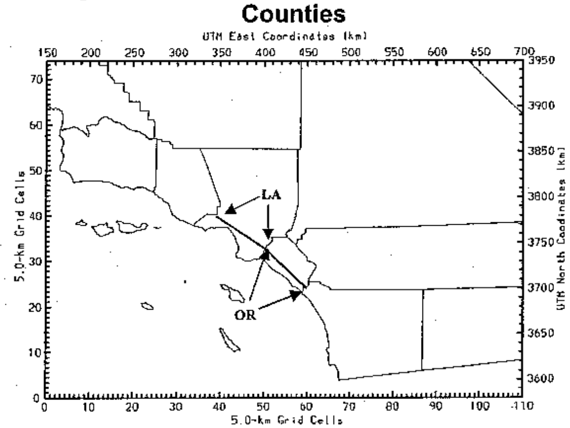
The mass flux into the SCAB for each lane and speed scenario was calculated by post-processing the CALGRID model output. Within the modeling domain, line segments were defined approximating the coastlines of Los Angeles and Orange Counties (see Figure V-15). The hourly net mass flux (HNMF, ton/hour) was calculated through the vertical planes defined by each of these line segments:

$$HNMF = (CONC) * (MDEN) * (AREA) * (WSPD) * \cos(WDIR - ANGLE)$$

where CONC = NO_x concentration (ppm)
MDEN = molecular density of NO_x corrected for pressure and temperature (ton-m^{-3}/ppm)
AREA = vertical crosssectional area of each grid cell along each line segment (m^2)
WSDP = wind speed (m/hour)
WDIR = wind direction
ANGLE = orientation angle of each line segment

The daily net mass flux (DNMF, ton/day) was calculated as the accumulated sums of the HNMFs for Los Angeles and Orange Counties, for each 24-hour period beginning at midnight (0000 PDT).

Figure V-15
Southern California Ozone Study Modeling Domain Showing Line Segments Defined for Calculating Mass Flow Rates into Los Angeles (LA) and Orange (OR) Counties



Shipping Emissions Preparation

Domain-wide emissions from each of the five alternative lane and speed control scenarios were calculated for each day of the period August 3-7, 1997 (see Chapter III). The numbers of ships, ship types, ship speeds, and NO_x emission rates were determined from day-specific records of ship traffic and are described in Chapter III. For the base case (existing shipping lane), daily total NO_x emissions from ships ranged from 34.81–67.35 tons/day. The total emissions from each of the speed control scenarios were less than that those from the base case while the total emissions from the alternative lane were greater than for the base case.

Air quality models generally do not describe emissions from moving sources such as ships very well. Emission rates can only be described as hourly rates, and ship locations can only be described within the resolution of the grid cell size (5 km in this analysis). Further, the vertical distribution of emissions from ships is determined from parameters such as stack height, exhaust temperatures, and exit velocity. Air quality models are coded to calculate the plume rise from stack sources from the stack parameters. However, moving point sources with varying emission rates and stack parameters are difficult to input into the model explicitly.

The emissions from the offshore shipping scenarios were incorporated into the CALGRID model by defining a separate point source for each ship, within each grid cell of the modeling domain in which that ship was found during the August 3-7 episode period. For each hour simulated, the grid cells in which each ship spent time were identified and the point source was given an emission rate proportional to the time that the ship spent within each grid cell. The CALGRID point source input file for the base case (current shipping lane) contained 7,276 sources. The daily total NO_x emissions in the input files were calculated to verify correct emission amounts.

Shipping emissions were not prepared from observations for the September 4-5 episode. To simulate the September 3-5 period, the emission files prepared for August 3-5 were used. August 3 and 4 represent the highest daily totals of shipping emissions during the episode.

August 3-7 Simulation Results

The simulation results for the period August 3-7, 1997 show that the net mass flux ("flux") into the SCAB varied widely from day to day. For the current shipping lane, the fluxes ranged from 3.85 tons/day on August 5, to 33.3 tons/day on August 4th (Table V-8). These flux differences can be attributed to differences in daily emissions totals and differences in wind flow patterns. The flux on August 3, while not the lowest of the 5-day period, was characteristically low for each of the lane and speed scenarios and may be attributed to the low initial concentrations at the beginning of the CALGRID simulation. The results from the first day of the simulation of each episode period (August 3 and September 3) should not be considered in comparisons among the lane and speed scenarios for this reason.

Table V-8
Daily Net Mass Flux (tons/day) into the South Coast Air Basin from August 3-7, 1997 Simulation

Scenario	Aug. 3	Aug. 4	Aug. 5	Aug. 6	Aug. 7
Current shipping lane	14.27	33.3	3.85	16.44	24.96
Speed control scenario #1	13.12	31.65	3.07	14.99	23.06
Speed control scenario #2	12.18	28.92	2.68	13.66	20.49
Speed control scenario #3	13.03	30.22	3.24	14.99	22.05
Proposed shipping lane	11.15	17.45	5.67	14.62	21.87

In general, the flux into the SCAB from the current shipping lane and the speed control scenarios were correlated with the emissions totals. For example, speed control scenario #2 had the lowest average total emissions, and among those scenarios within the existing shipping lane, resulted in the lowest flux. The flux resulting from the proposed lane, however, showed a less consistent pattern compared with the other scenarios. On August 4, the flux from the proposed lane was the lowest among the scenarios with 17.45 tons/day. On August 6 and 7, the flux from the proposed lane was slightly higher. On August 5, the fluxes for all of the scenarios were relatively low (the offshore winds on this day were calm), however the flux from the proposed lane was highest among the alternatives.

<u>September 3-5 Simulation Results</u>

The simulated flux into the SCAB for September 3-5, 1997 showed characteristics that were similar to results from the August period (Table V-9). For each of the lane and speed scenarios, the flux on September 3 was much less than on September 4 and 5, suggesting the influence of the low initial conditions on the simulation results. Among the current shipping lane and speed control scenarios, the fluxes were correlated with total daily emissions. For example, speed control scenario #2 had the lowest emissions and the lowest flux among all scenarios within the current shipping lane.

Table V-9
Daily Net Mass Flux (tons/day) into the South Coast Air Basin from September 3-5, 1997 Simulation

Scenario	Sept. 3	Sept. 4	Sept. 5
Current shipping lane	10.3	31.63	22.5
Speed control scenario #1	9.64	30.27	20.45
Speed control scenario #2	9.33	28.47	18.7
Speed control scenario #3	9.57	29.7	20.28
Proposed shipping lane	7.83	14.86	35.76

The flux from the proposed shipping lane varied widely. On September 4, the flux into the SCAB was approximately 15 tons, about one-half of any of the other scenarios. However, on September 5 the flux from the proposed shipping lane was almost 36 tons, and was more than 50% greater than for any of the other scenarios.

Discussion of Simulation Results

The simulation results help to illustrate the complexity of the problem of determining the impacts of offshore emissions from shipping on onshore air quality. The wide day-to-day variations in the flux from these emissions into the SCAB for each of the lane and speed control scenarios demonstrated the importance of meteorological flow patterns in determining the flux. Changing the location of the offshore emissions through the use of an alternative shipping lane can either increase or decrease the relative impact of these emissions.

The simulation results suggest that the "carryover" of emissions from one day to the next may significantly impact onshore air quality. In both the August 3-7 and September 3-5, 1997 simulation periods, the flux on the first day was much less than for the other days (except for August 5) even though the offshore emissions on these two days were among the highest during the periods simulated (Figures V-16 and V-17). This was attributed to the low initial concentrations defined at the start of each period. However, this indicates that emissions from the previous day can be important in determining the onshore mass flux on subsequent days.

The simulation results also suggest that the benefits of relocating the emissions to an alternative shipping lane are dependent on the day-to-day variations in offshore wind flow patterns. This was most clearly illustrated in the simulation results for the September 3-5, period. On September 5, the flux from the proposed shipping lane was more than four times higher than on September 4, even though the emissions on September 5 were only about half of those on September 4. Meteorology was also an important factor in determining mass flux on August 5, when the fluxes for all scenarios were near zero.

Figure V-16
Simulated Net Mass Flux of NO_x into the SCAB from Offshore Shipping (August 3-7, 1997)

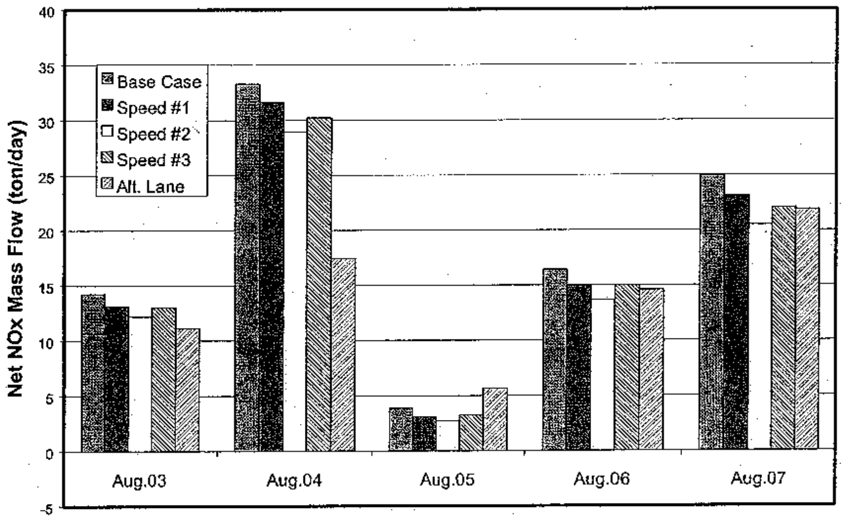
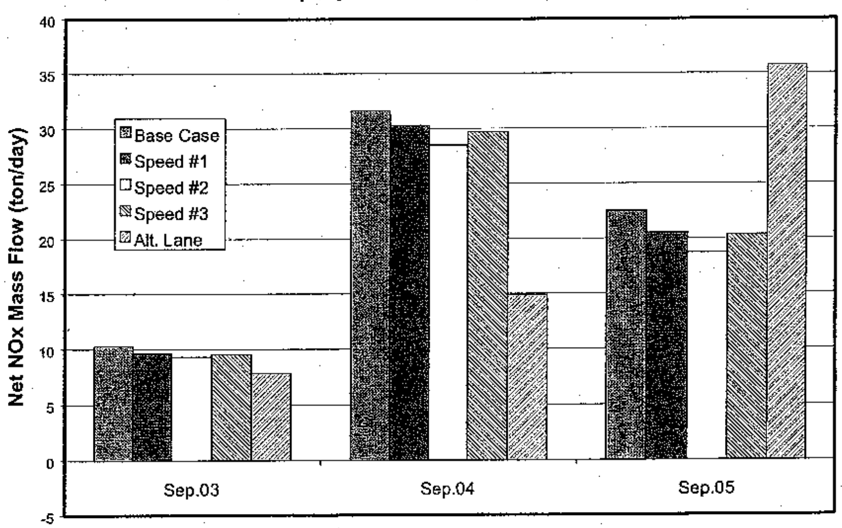


Figure V-17
Simulated Net Mass Flux of NO_x into the SCAB from Offshore Shipping (September 3-5, 1997)



Sensitivity Analyses

Sensitivity analyses are air quality model simulations in which inputs to the model are altered to assess the influence of those inputs on the output of the model. This influence is determined by comparing the simulation results with those of an unaltered, or reference, case.

Sensitivity analyses are performed for two reasons. The first reason is to determine the relative stability of the simulation results. If the simulation results vary widely in response to small changes in the model inputs, then it suggests that there is a greater uncertainty in the results. The second reason is to understand the relative importance of the various input parameters and fields. If the simulation results from the model are especially sensitive to a particular input parameter, then perhaps more care should be used in the determination of that parameter.

This section describes sensitivity analyses that were done for the August 3-7 and September 3-5, 1997 simulations of NO_x emissions from offshore shipping. For these sensitivity analyses, the reference cases were taken as the simulations done to determine the mass flow into the South Coast Air Basin (described previously). The input parameters and fields selected for alteration were those that could potentially have the greatest influence on the simulation results.

- ***Temporal Patterns in Daily Offshore Emissions–August 3-7, 1997 Episode***

As noted previously, daily totals of offshore NO_x emissions varied widely. For example, on August 4, the emissions totaled 67.35 tons and on August 5, 34.81 tons (see Chapter III). There was also a significant hourly variation in emissions within each day. For example, on August 5 the offshore emissions were approximately 4 tons/hour at 0000 PDT, but after 0200 PDT were less than 2 tons/hour (FigureV-18). On August 4, the emissions were 5 tons/hour at 0000 PDT, dropped below 2 tons/hour near mid-day, but increased to more than 3 tons/hour after 1800 PDT. Since wind flow patterns are dependent on time of day, the diurnal pattern of emissions may also influence the relative mass fluxes among the proposed shipping lane and speed control scenarios. Therefore, in this analysis, the emissions for August 4 were used for each day of the 5 day episode.

Figure V-18
Hourly NOx Emissions from Offshore Shipping–Current Shipping Lane

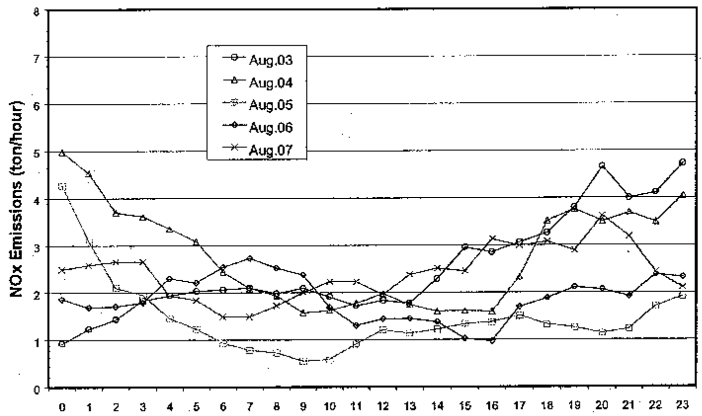
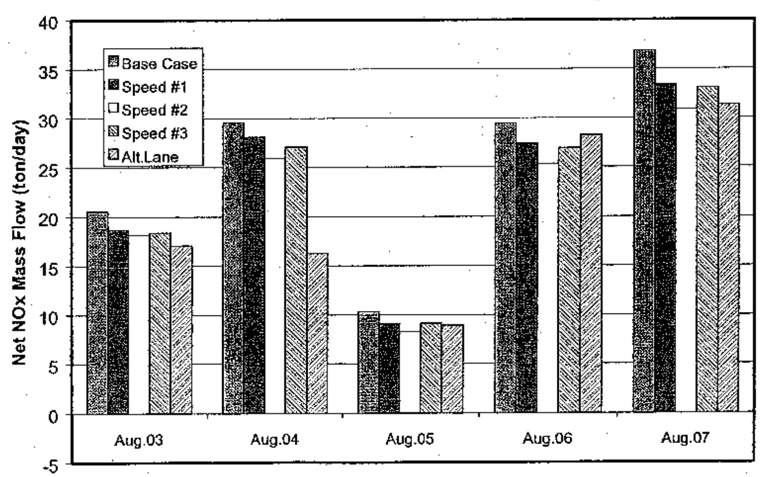


Figure V-19 shows the results of this sensitivity simulation. Comparing these results to those from the reference case (Figure V-16), it can be seen that except for August 4, the net mass flux into the SCAB was increased for each day of the simulation, for each of the alternative lane and speed scenarios. The daily emissions on August 3 were less than those on August 4; however, the emissions during the second half of August 3 were greater than for the same time period on August 4 (see Figure V-18). Thus, replacing the August 3 emissions with those from August 4 resulted in less day-to-day carryover of emissions offshore and contributed to a reduced mass flow into the SCAB on August 4.

Figure V-19
Net Mass Flux into the SCAB with Constant Daily Emissions



Compared with the reference case (Figure V-17), using the August 4 emissions for each day of the simulation changed the mass flux into the SCAB. For each of the days simulated, the current shipping lane had a greater mass flux than did the speed control scenarios. Therefore, changing the offshore emissions did not change the relative differences among these scenarios. The relative differences between the current and alternative shipping lanes did change, however. For example, in the reference case simulation for August 5, the alternative lane had a mass flow rate that was higher than for the current lane by approximately 2 tons/day. In this, analysis, the mass flow from the current lane was the higher of the two scenarios.

The results of this analysis suggest that the diurnal pattern of offshore emissions does not alter the relative mass flux rates between the base case (current shipping lane) and the speed control scenarios. The diurnal pattern of offshore emissions has a greater influence on the relative difference in onshore mass flux between the base case and the proposed shipping lane. However, the differences observed were relatively small compared with the extremes in the differences in mass flux seen on August 4.

- *Plume Rise -- September 3-5, 1997 Episode*

Within the CALGRID model, the ships represented in the analysis of offshore emissions were treated as elevated point sources. The effective plume heights (the heights at which the emissions were injected into the modeling domain) were calculated from estimates of stack heights, exhaust temperatures, and volume flow rates. For most ships, the resultant plume heights were between 150 and 325 m. However, the algorithms used to calculate these plume heights were developed for stationary point sources. The applicability of these algorithms to moving sources is unknown, however wind speed is known to reduce plume heights and moving ships would presumably have higher relative wind speeds. Also, wind speeds and directions within the California Bight are known to change with height. Therefore, exhaust plume injected at different heights may encounter different wind flow patterns. For this sensitivity analysis, the plume rise calculated within the CALGRID model was scaled (reduced) by factors of 0.5 and 0.1 to determine if the simulation results were sensitive to the plume rise algorithms (only the base case, speed control scenario #2, and the alternative lane were simulated). Figures V-20 and V-21 show the results of these sensitivity simulations.

Figure V-20
Mass Flux into the SCAB with Plume Rise Scaled by 0.1

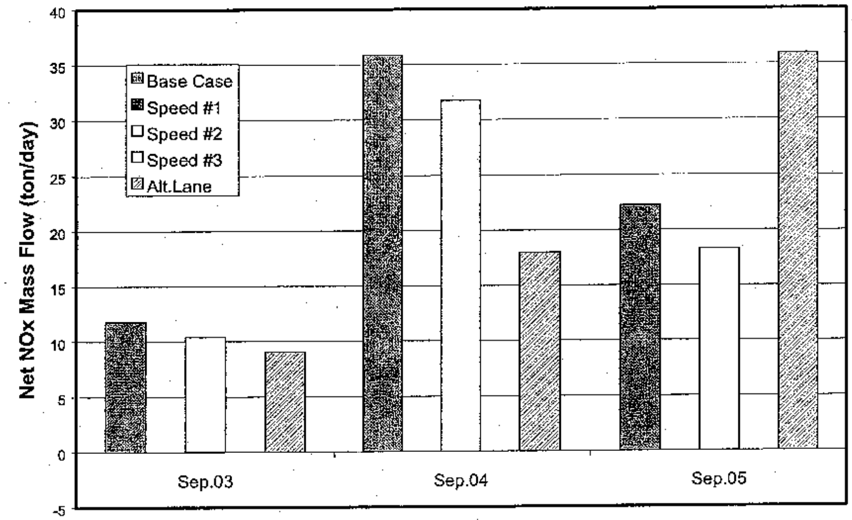
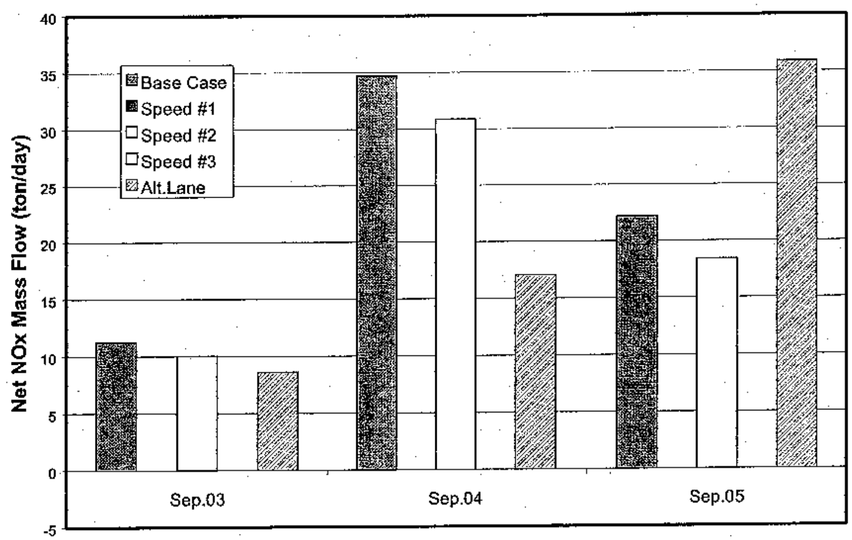


Figure V-21
Mass Flux into the SCAB with Plume Rise Scaled by 0.5



Compared with the reference case (Figure V-17), reducing the plume heights slightly increased the mass flux on September 3 and 4, but resulted in little change on September 5. For example, for the reference case, the base case scenario resulted in a mass flux into the SCAB of 32 tons on September 4. Scaling the plume rise by a factor of 0.5 resulted in a mass flow of 36 tons. However, comparing the relative differences between the base case, speed control, and alternative lane scenarios, reducing the plume height made little difference. Also, the differences in mass flux between the simulation results based on a scale factor of 0.5 and those based on a scale factor of 0.1 were small.

The results of this analysis showed that varying the effective plume heights of the offshore sources resulted in small increases in the mass flux into the SCAB. However, changes in the relative differences among the alternative lane and speed control scenarios were small.

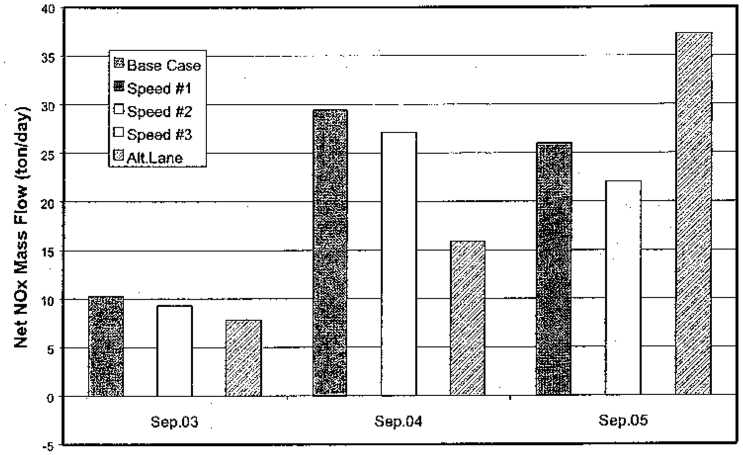
- *Wind Field Adjustment -- September 3-5, 1997 Episode*

Wind speeds and directions can change with height within the California Bight. This is often evident when comparing wind measurements at different sites on San Clemente Island. The San Clemente sites are at elevations ranging from 50 m to 550 m and wind directions can often vary by as much as 90 degrees. Ground-based measurements of vertical wind profiles (base elevation of 50 m) also show marked changes in wind directions between 50 m and 200 m.

The observed differences in wind speed and directions with height on San Clemente Island make the selection of wind observations for use in the development of the wind fields difficult. Measurements from the site at lower elevations are likely to be more representative of winds within the surface boundary layer. However, boundary-layer heights are not well known, and shipping emissions are represented in the model as elevated point sources for which winds at higher elevations may be more representative of those influencing the shipping emission release points.

In the wind field developed for the reference case, the wind measurements from the higher elevation (CLEM) on San Clemente Island were used. For this sensitivity analysis, the wind measurements from the lower elevation were used (additional measurements for Buoy 46046, located at the western end of the Santa Barbara Channel, were also included) to develop an alternative wind field. The objective of this analysis was to investigate how the changes in the resultant alternative wind field would influence the reference case simulation results (see Figure V-22).

Figure V-22
Mass Flux into the SCAB Using an Alternative Wind Field



Compared with the reference case simulation (Figure V-17), the alternative wind field resulted in only small changes in the onshore mass fluxes. For example, on September 4 the alternative wind field resulted in a mass flux from the base case scenario of 32 tons, while from the reference case it was 29 tons. The relative mass flow rates among the base case, speed control scenario #2, and the alternative lane were changed only slightly.

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VI

COMPARATIVE ANALYSES AND FINDINGS

In this chapter we summarize the conclusions reached from the tracer study and the air quality modeling simulations. As previously discussed, the tracer study provided data that would allow for a qualitative comparison of the onshore impacts (dispersion only) between the proposed and existing shipping lanes. In addition to the analysis of the tracer study data, modeling simulations were conducted to numerically compare the onshore impacts from each of the proposed control strategies – relocation of the shipping lane and voluntary speed reduction. As per the TWG, the modeling simulations did not consider photochemistry, due to the non-availability of a complete emissions inventory for the SCOS episodes and time considerations. We also include a brief summary of the findings and our recommendations to U.S. EPA to consider in their deliberations on a suitable control strategy to provide the emission reductions needed from marine vessels in the 1994 Ozone SIP. Our conclusions and findings are limited to an analysis of the impacts on the SCAQMD. As discussed previously, the TWG agreed to limit the analysis to the SCAQMD with the understanding that U.S. EPA may need to take into consideration the impacts on upwind and downwind regions when determining the most appropriate operational control for marine vessels.

A. TRACER STUDY ANALYSIS

The tracer study provided data on the trajectory and dispersion of ship emissions released from ships traversing the existing shipping lane and the proposed relocated shipping lane. The data collected allows for comparison between the differences in dispersion for the morning and afternoon periods on 3 days – August 23, 1997, September 4, 1997 and October 4, 1997. By looking at the dispersion characteristics qualitative information can be gleaned regarding the potential for onshore air quality impacts due to NO_x emissions from ships traveling in the shipping lanes along the coast. Greater dispersion implies the emissions are dispersed over a larger area or volume, resulting in lower concentrations of the pollutant available to participate in the photochemical reactions that form ozone and particulate matter. If dispersion is greater when ships are traveling along a particular shipping lane, presumably the emissions from those ships would have less potential impact on air quality than ships traveling along a lane that demonstrates less dispersion.

To assess the dispersion of emissions from the existing and proposed shipping lanes, the average normalized station peaks of the tracer measurements were determined and the ratios of impacts were calculated. These ratios, which were first presented in Table

IV-13 are shown again in Table VI-1 below. Ratios less than 1.0 imply greater dispersion from the proposed lane and those greater than 1.0 imply less dispersion from the proposed lane. Ratios near 1.0 imply similar dispersion for the two lanes.

Table VI-1
Ratios* of Proposed Shipping Lane Impact to Current Shipping Lane Impact in the South Coast AQMD

	Ratio for Morning Release	Ratio for Afternoon Release
August 23, 1997	0	1.79
September 4, 1997	0.40	0.21
October 4, 1997	N/A	0.99

The ratio of average normalized station peak concentrations for the proposed lane to that from the current lane, from Table IV-12

The data do not demonstrate a consistent pattern. While the ratios for the morning releases demonstrate greater dispersion from the proposed shipping lane on the tracer release days, the afternoon releases did not show any consistency. For the afternoon releases, there was less dispersion from the proposed lane on the August 23rd release date, more on September 4th and similar dispersion from the existing and proposed shipping lanes on the afternoon of October 4, 1997. These results suggest that meteorology influences the direction and the magnitude of dispersion from ship emissions. Wind circulation patterns in the area offshore of Southern California can be very complex. Day to day, as well as diurnal, differences in wind directions can be very great and in turn can impact transport and diffusion mechanisms in the region.

B. MODEL SIMULATIONS

Model simulations were developed for two episode periods, August 3-7, 1997 and September 3-5, 1997, using an Eulerian air quality modeling system. In each case, the emissions of NO_x from each of the five control strategies were simulated without photochemistry and the net onshore mass flux into the SCAQMD was calculated. To assess the relative impacts of shipping emissions from the shipping lane and speed scenarios representing each control strategy, comparisons of the mass flux among the control scenarios were made to assess the relative impacts of shipping emissions. The accumulated mass flux and its distribution along the shoreline provide an indicator of the impact of offshore emissions on onshore air quality – the lower the mass flux, the lower the potential influence on onshore air quality. When comparing control strategies, the emissions from the control strategy with the lowest mass flux into the SCAQMD would therefore have the least effect on onshore air quality.

The results from the simulations are presented in Table VI-2. The data from August 3rd and September 3rd are not included. As explained previously, data on these days may not be representative because they are start-up days for the modeling simulations and may be overly influenced by initial conditions.

Table VI-2
Daily Net Mass Flux (tons/day) into the South Coast Air Basin from Simulation Results for August 4-7 and September 4-5, 1997

Scenario	Aug. 4	Aug. 5	Aug. 6	Aug. 7	Sept. 4	Sept. 5
Current shipping lane	33.30	3.85	16.44	24.96	31.63	22.5
Speed control scenario #1	31.65	3.07	14.99	23.06	30.27	20.45
Speed control scenario #2	28.92	2.68	13.66	20.49	28.47	18.70
Speed control scenario #3	30.22	3.24	14.99	22.05	29.70	20.28
Proposed shipping lane	17.45	5.67	14.62	21.87	14.86	35.76

Some qualitative conclusions can be drawn from the simulation results. First, there is a mass flux benefit for all of the voluntary speed reduction alternatives for all the days simulated. While the magnitude varied from day to day, it correlates well with the expected emission reductions from each scenario. Scenario #2, which requires the most reduction in speed over a long distance and results in the greatest emission reductions in the SCAB inventory, demonstrated the largest reduction in the net mass flux for the three speed control scenarios. Similar to the results from the tracer study, the results from the model simulation of the proposed shipping lane did not reveal a consistent pattern. On two days, the largest benefit was seen from this control strategy, about a 50% reduction in flux, however, on both August 5th and September 5th, the mass flux was actually greater than that simulated for the base case. As discussed in Chapter V, it appears that the benefits from moving the shipping lane further offshore are highly dependent on the variable offshore wind flow patterns.

Obviously the days simulated represent a small subset of the total days in the SCAB. Therefore to put the modeling results in perspective, it would be useful to know how frequently the types of days simulated occur. To address this question, a meteorological classification analysis based on the meteorology and air quality from 1997 was conducted (see Appendix C). In this analysis, the 1997 days were sorted into frequency nodes, where a node represents a type of episode day. This analysis showed that the August and September episode days represent meteorological patterns that occur approximately 30% of the time and reflect 3 of the 6 types of days that have medium to high ozone potential in the SCAB.[5] Table VI-3 summarizes the results of the meteorological classification analysis.

[5] The weather patterns in 1997 reflected a reduced ozone potential indicative of the El Nino weather circulation that was building that summer.

Table VI-3
Frequency of Occurrence for the Types of Days Simulated
(from Appendix C)

Day Simulated	Episode Node (or Type of Day)	Frequency of Occurrence in 1997
August 4	9	7.1%
August 5	9	7.1%
August 6	9	7.1%
August 7	10	1.9%
September 4	10	1.9%
September 5	6	22.2%

As a potential further aid in interpreting the results of the modeling simulations, the modeling results for the days simulated (from Table VI-2) were combined with their frequency of occurrence to derive a weighted average reduction in net mass flux relative to the base case. Since there were multiple simulation days in nodes 9 and 10, the fluxes were first averaged for the days in those nodes before combining with the frequency of occurrence. The results of this analysis are presented in Table VI-4 below. As shown, the greatest benefit is demonstrated from the simulation of speed control scenario #2. In this scenario, the precautionary zone speed limit of 12 knots is extended to the overwater boundary of the SCAB and resulted in approximately a 16% decrease in flux onshore. Speed control scenarios #1 and #3 had comparable benefits at 8% and 10% reduction respectively, and the proposed relocated shipping lane had the least benefit.

Table VI-4
Average Weighted Percent Change in Net Mass Flux (tons/day) into the South Coast Air Basin from Simulation Results for August 4-7 and September 4-5, 1997

Scenario	Average Flux by Node (tons/day)			Weighted Average Flux* (tons/day)	Change in Weighted Flux from Base Case
	Node 9 *(Aug. 4, 5, 6)*	Node 10 *(Aug. 7, Sept. 4)*	Node 6 *(Sept. 5)*		
Current shipping lane	17.86	28.30	22.50	6.80	-
Speed control scenario #1	16.57	26.67	20.45	6.22	-8%
Speed control scenario #2	15.09	24.48	18.70	5.69	-16%
Speed control scenario #3	16.15	25.88	20.28	6.14	-10%
Proposed shipping lane	12.58	18.37	35.76	9.18	+35%

* Σ (node average) x (node frequency) for each of the nodes

Because of the limited number of days simulated, it is important to keep in mind the following caveats when interpreting the results in Table VI-4:

- A total of six days were simulated, representing meteorological patterns that occur approximately 30% of the time and reflect 3 of the 6 types of days that have medium to high ozone potential in the SCAB. However, the other three types of days with medium to high ozone potential were not captured.

- A single day (September 5) was used in the weighted average flux calculation for node 6, whereas there were multiple days available for the other two nodes. As shown in Table VI-2, fluxes for different days with the same node type can vary. It is not known how representative the September 5 flux is for an average node 6 day.
- The frequency distribution of meteorological patterns in 1997 is not necessarily representative of other years.

During the TWG discussions, questions were raised regarding how the results could be used to estimate the emission reductions with respect to the SIP. Consistent with current practices, the expected emission reductions that can be claimed for SIP credit are determined from the actual change in the emissions inventory (for South Coast Air Basin) – not a reduction based on photochemical model simulations. To approximate potential SIP credit for the different control strategies we calculated a control factor based on the emissions estimates for each control strategy as compared to the base case (i.e. a percent reduction or increase in emissions). This control factor was then applied to the forecasted inventory for marine vessels in 2010. Since the controls would only be applied during the cruising mode (not maneuvering or hotelling), the control factor was only applied to that portion of the inventory that represented ships in the cruise mode. Because we did not have an ungridded emissions estimate for the proposed shipping lane, the estimate for the proposed shipping lane is based on a control factor calculated from the gridded inventory. Three key assumptions with this approach are: 1) ship type and activity in 2010 is similar to the activity during the August 3-7, 1997 episode, 2) the ship activity during the August 3-7, 1997 episode is representative of a typical summer day, and 3) the gridded emissions for the proposed shipping lane provide a good approximation of the ungridded emissions inventory. As shown in Table VI-5, Speed control scenario #2 approaches the 1997 Ozone SIP (and 1994 Ozone SIP) M-13 target for the voluntary control strategies. In the 1997 SIP, the planned reductions for M-13 expected a 29% reduction in the cruising emissions from the ocean going fleet in the SCAB.

Table VI-5
1997 SIP Emission Reduction Estimates
Tons per Day NOx

Control Strategy	Expected Emission Reductions	Percent Change	Control Factor	1997 SIP Estimated Reductions (2010)*
Speed control scenario #1	-2.96	-10.5%	0.11	-2.9
Speed control scenario #2	-6.53	-28.5%	0.28	-7.3
Speed control scenario #3	-3.98	-18.8%	0.19	-4.9
Proposed shipping lane	+0.51	+2.2%	0.02	+.52

*To determine the estimated reductions, the control factor was applied to the 1997 SIP projected 2010 NOx emissions (26.2 T/D) for ocean-going vessels calling on the POLB and POLA while in the cruising mode. These emission reduction estimates already account for the precautionary speed zone reduction requirement that was instituted in 1994 since the forecasted inventory is based on a 1997 SCAB baseline inventory.

C. SUMMARY OF FINDINGS

Based on the results from the tracer analysis and the modeling simulations, it can be concluded that a voluntary speed reduction control strategy would likely result in consistent emission reduction benefits in the SCAB with the magnitude of the benefits dependent on the extent of the speed reductions and the time spent in the reduced speed mode. Control Scenario #2, which requires a speed limit of 12 knots between the ports and the SCAB overwater boundary, appears to provide the greatest benefit with respect to both NO_x emissions and the flux of NO_x emissions that reach onshore, demonstrating approximately a 28% reduction in the emission inventory and a 16% reduction in flux when compared to the base case. Although the control strategy to move the shipping lane further offshore does provide benefits on certain types of days, it does not appear to provide a consistent benefit and it is not possible to reach definitive conclusions about this strategy. Because the modeling simulations did not consider photochemistry, it is also not possible at this time to determine the comprehensive air quality impacts relative to ozone and particulate matter formation attributed to NOx emissions from marine vessels from the various alternatives. To understand the comprehensive air quality impacts, comprehensive photochemical and aerosol modeling should be conducted. For the next SCAQMD Air Quality Management Plan update photochemical and aerosol modeling will be performed and should provide additional information on the impacts of shipping emissions on ozone and fine particulate formation.

APPENDIX A

Scope of Analysis

Appendix A

SCOPE of ANALYSIS

Throughout the working group process, a number of issues were raised on which the TWG reached consensus that the issues were beyond the scope of the comparative analysis being conducted by the TWG. In this appendix, we provide a brief description of the main issues that were identified. The U.S. EPA intends to work with members of the TWG to evaluate any issues that may need to be addressed before making a decision on the most appropriate operational control strategy for marine vessels

Future Ship Speeds: The baseline emissions inventory is based on the estimated ship speeds for the current fleet of ships using the POLA and POLB. The TWG believed accurate data was not available to project the ship speeds that would occur in future years (i.e. 2010). Due to time constraints and lack of data, the comparative analysis is limited only to the current inventory; no projections were made for the future impact of any of the proposed control strategies. The future ship speeds and their impact on the emissions inventory and potential emission reductions from any control strategy may need to be considered when determining the most appropriate operation control for marine vessels.

Photochemical Modeling: Ship emissions can be involved in complex overwater chemical reactions which may impact the amount of NOx emissions that reach the shoreline. Because of time constraints and the unavailability of the complete modeling emissions inventory for SCOS97, the TWG agreed to use dispersion modeling to assess the on-shore impacts of the shipping emissions relative to the quantity of emissions that reach shore in the SCAB. Photochemical modeling will not be ignored however, as photochemical modeling will be conducted during the development of the next comprehensive plan update (AQMP update) for the SCAQMD, expected final in 2001. Photochemical modeling is needed for the attainment demonstration for the 1-hour federal ozone standard and will provide additional information about the impact of shipping emissions on ozone, PM_{10} and toxics. For the next AQMP update the preferred control strategy will be included in the modeling exercise to help quantify the benefits of the overall control strategy on peak ozone and population exposure. We do not believe this will result in a change in our conclusions regarding the dispersion impacts of shipping emissions; however, once the chemistry is included in the modeling simulations, we may find that there are significant PM_{10} benefits from reducing NOx emissions from ships offshore.

Impacts Beyond SCAB Boundaries: Both of the control strategies evaluated may have the potential to shift the impact of ship emissions to areas outside the SCAB. The TWG had numerous discussions on what areas may be impacted and whether such a shift in emissions would occur. However, the TWG agreed that determining impacts outside the SCAB was beyond the scope of the comparative analysis may need to be considered when determining the most appropriate operational control for marine vessels.

Economic, Logistic and Other Impacts of Potential Control Strategies: There were numerous discussions on the impacts of the proposed control strategies including impacts on the U.S. Navy's Sea Range off the southern California coast and the loss of time and income that may occur if ships take longer to approach the ports due to travelling along an alternative route or traveling at a reduced speed. These impacts were outside the scope of the TWG's comparative analysis; however, the TWG agreed this may need to be considered when proposing a control strategy for marine vessels.

Appendix B

Day Specific Ship Activity Information And Emissions

Summary of Activity and Emissions Data for the August 3-7, 1997 SCOS97 Episode

In table B-1 we provide a detailed summary of the ship activity and emissions data for the August 3-7, 1997 episode. This includes information on the ship type, date, time, and direction of arrival and departure in the South Coast waters and the parameters used to calculate the NOx emissions. Additional parameters provided by the Marine Exchange but not included in this Table are call signs, previous port, next port, speed, initial berth, type of cargo, gross tonnage, and net tons. The following abbreviations are used to identify the ship types: Bulk Carrier (BBU); Bulk/Container Carrier (BCB); General Cargo (GGC); Refrigerated Cargo (GRF); Passenger (MPR); Vehicle Carrier (MVE); Chemical Tanker (TCH); Tanker (TTA); Container Carrier (UCC); and RORO Container Carrier (URC). In Table B-2 information on U.S. Navy ships is provided. In addition, we have included information on other pollutant emission estimates for the ships included in the inventory for the August 3-7 1997 SCOS97 episode as well as the methodology followed to estimate the emission benefits of the precautionary speed zone.

Table B-1

Activity Data and NOx Marine Vessel Inventory for the August 3-7, 1997 Episode

													Cruise						
Ship Name	Vessel type	Engine Type	# Eng.	Cycle	Actual Avg./Corrected speed	Arrive Gate	Arrive Dir	Arrive Date, Time	Depart Gate	Dept. Dir	Depart Date, Time	Aug 3-7th only-Hrs at Port	Entry Cruise for 3,4,5,6,7 (Y/N)	Exit Cruise for 3,4,5,6,7 (Y/N)	Entry Cruise Dist. (nmiles)	Entry Cruise Time (hours)	Exit Cruise Dist. (nmiles)	Exit Cruise Time (hours)	Actual HP Llyods
BEL ACE	BBU	D	1	2	12.46	QUEEN	S	8/3/97 10:10	QUEEN	N	8/3/97 14:35	4.42	Y	Y	34	2.73	39	3.13	11100
FARENCO	BBU	D	1	2	13.79	QUEEN	N	8/3/97 16:45	ANGEL	N	8/23/97 10:25	103.23	Y	No	40	2.90	39	2.83	19429
FIVI	BBU	D	1	2	14.42	ANGEL	N	8/2/97 16:10	ANGEL	N	8/9/97 16:35	119.98	No	No	40	2.77	39	2.70	11600
MODI	BBU	D	1	2	13.35	QUEEN	N	8/4/97 1:00	QUEEN	S	8/4/97 12:30	11.50	Y	Y	40	3.00	38	2.85	13100
NOSHIRO MARU	BBU	D	1	2	12.46	ANGEL	N	7/31/97 17:15	ANGEL	N	8/6/97 17:50	89.83	No	Y	40	3.21	39	3.13	11070
OTRADA	BBU	D	1	2	15.75	ANGEL	N	7/31/97 4:10	ANGEL	S	8/3/97 14:15	14.25	No	Y	40	2.54	38	2.41	13320
PERICLES C.G.	BBU	D	1	2	13.80	QUEEN	N	8/1/97 22:20	QUEEN	S	8/3/97 19:35	19.58	No	Y	40	2.90	38	2.75	17400
SAGACIOUS NIKE	BBU	D	1	2	13.80	QUEEN	N	8/4/97 15:15	QUEEN	N	8/12/97 3:50	80.73	Y	No	40	2.90	39	2.83	9750
SINGAPORE ACE	BBU	D	1	2	11.93	QUEEN	N	8/6/97 1:35	QUEEN	N	8/22/97 5:10	46.40	Y	No	40	3.35	39	3.27	15800
PACPRINCE	BCB	D	1	2	13.04	QUEEN	N	8/5/97 9:00	QUEEN	S	8/6/97 6:35	21.58	Y	Y	40	3.07	38	2.91	9500
PACPRINCESS	BCB	D	1	2	13.62	QUEEN	S	8/6/97 13:40	QUEEN	N	8/8/97 15:15	34.32	Y	No	34	2.50	39	2.86	9500
STAR DROTTANGER	BCB	D	1	2	13.35	ANGEL	S	8/5/97 4:50	ANGEL	S	8/6/97 21:20	40.50	Y	Y	34	2.55	38	2.85	13100
KARINA BONITA	GGC	D	1	2	15.29	QUEEN	N	8/3/97 9:35	QUEEN	S	8/5/97 5:25	43.83	Y	Y	40	2.62	38	2.49	11200
STAR GRIP	GGC	D	1	2	14.79	ANGEL	N	8/3/97 15:25	ANGEL	S	8/3/97 23:40	8.25	Y	Y	40	2.70	38	2.57	10120
VAIMAMA	GGC	D	1	4	13.90	QUEEN	S	8/3/97 6:50	QUEEN	N	8/4/97 2:40	19.83	Y	Y	34	2.45	39	2.81	8090
CHIQUITA FRANCES	GRF	D	2	4	18.20	QUEEN	S	8/7/97 3:55	QUEEN	S	8/8/97 9:05	20.07	Y	No	34	1.87	38	2.09	16213
MAGIC	GRF	D	1	4	18.20	QUEEN	S	8/4/97 6:10	QUEEN	S	8/5/97 3:20	21.17	Y	Y	34	1.87	38	2.09	8937
TUNDRA KING	GRF	D	1	2	18.20	ANGEL	N	8/4/97 6:40	ANGEL	S	8/4/97 19:35	12.92	Y	Y	40	2.20	38	2.09	13250
HOLIDAY	MPR	D	1	2	11.70	ANGEL	S	8/4/97 6:15	ANGEL	S	8/4/97 18:15	12.00	Y	Y	34	2.91	38	3.25	31973
JUBILEE	MPR	D	1	2	12.73	ANGEL	S	8/3/97 7:05	ANGEL	S	8/3/97 17:20	10.25	Y	Y	34	2.67	38	2.99	31962
VIKING SERENADE	MPR	D	1	2	11.00	ANGEL	S	8/4/97 6:25	ANGEL	S	8/4/97 17:30	11.08	Y	Y	34	3.09	38	3.45	27000
AYA II	MVE	D	1	4	16.38	ANGEL	S	8/6/97 10:55	ANGEL	N	8/6/97 19:35	8.67	Y	Y	34	2.08	39	2.38	16880
BELLONA	MVE	D	1	2	16.38	QUEEN	N	8/4/97 8:40	QUEEN	N	8/5/97 4:25	19.75	Y	Y	40	2.44	39	2.38	11560
FRANCONIA	MVE	D	1	2	16.11	QUEEN	S	8/7/97 20:50	QUEEN	N	8/8/97 16:25	3.15	Y	No	34	2.11	39	2.42	12480
GREEN LAKE	MVE	D	1	2	16.61	QUEEN	N	8/6/97 23:15	QUEEN	N	8/7/97 18:50	19.58	Y	Y	40	2.41	39	2.35	13119
HUAL CARMENCITA	MVE	D	1	2	16.70	ANGEL	N	8/7/97 9:55	ANGEL	N	8/7/97 23:55	14.00	Y	Y	40	2.40	39	2.34	1300
OPAL RAY	MVE	D	1	2	16.47	ANGEL	N	8/3/97 20:50	ANGEL	N	8/8/97 15:30	99.15	Y	No	40	2.43	39	2.37	12400
STOLT TENACITY	TCH	D	1	2	15.13	QUEEN	W	8/5/97 19:30	QUEEN	S	8/9/97 5:30	52.48	Y	No	43.5	2.88	38	2.51	17400
BT NESTOR	TTA	D	1	2	14.69	QUEEN	S	8/2/97 10:25	QUEEN	S	8/4/97 3:35	27.58	No	Y	34	2.32	38	2.59	16799
SAMUEL GINN	TTA	D	1	2	13.08	QUEEN	W	8/6/97 23:20	QUEEN	N	8/8/97 2:15	24.65	Y	No	43.5	3.33	39	2.98	18900
ACAPULCO	UCC	D	1	2	20.02	ANGEL	S	8/6/97 5:30	ANGEL	N	8/7/97 19:25	37.92	Y	Y	34	1.70	39	1.95	30991
ALLIGATOR BRAVERY	UCC	D	1	2	21.48	ANGEL	N	8/5/97 18:15	ANGEL	N	8/7/97 14:00	43.75	Y	Y	40	1.86	39	1.82	46960
APL SINGAPORE	UCC	D	1	2	24.10	ANGEL	N	7/31/97 18:10	ANGEL	N	8/6/97 3:40	75.67	No	Y	40	1.66	39	1.62	66398
AXEL MAERSK	UCC	D	2	2	22.02	QUEEN	N	8/2/97 6:30	QUEEN	N	8/3/97 19:45	19.75	No	Y	40	1.82	39	1.77	45800
BRISBANE STAR	UCC	D	1	2	18.66	ANGEL	N	8/7/97 12:35	ANGEL	N	8/12/97 18:25	11.40	Y	No	40	2.14	39	2.09	29000
BROOKLYN BRIDGE	UCC	D	1	2	19.37	QUEEN	N	8/2/97 5:20	QUEEN	N	8/4/97 17:25	41.42	No	Y	40	2.07	39	2.01	37440
CALIFORNIA JUPITER	UCC	D	1	2	20.02	ANGEL	N	8/7/97 4:45	ANGEL	N	8/8/97 21:05	19.23	Y	No	40	2.00	39	1.95	29520
CALIFORNIA SATURN	UCC	D	1	2	20.02	ANGEL	S	8/7/97 13:50	ANGEL	N	8/8/97 18:50	10.15	Y	No	34	1.70	39	1.95	29610
CAPE CHARLES	UCC	D	1	2	20.02	ANGEL	S	8/1/97 14:00	ANGEL	N	8/3/97 3:10	3.17	No	Y	34	1.70	39	1.95	32800
CHASTINE MAERSK	UCC	D	1	2	16.84	QUEEN	S	8/5/97 21:05	QUEEN	S	8/8/97 3:30	50.90	Y	No	34	2.02	38	2.26	14248
CHETUMAL	UCC	D	1	2	21.39	ANGEL	N	8/5/97 6:15	ANGEL	S	8/6/97 19:30	37.25	Y	Y	40	1.87	38	1.78	38542
DIRECT EAGLE	UCC	D	2	4	17.09	ANGEL	N	8/6/97 7:05	ANGEL	S	8/8/97 6:55	40.90	Y	No	40	2.34	38	2.22	22799
DOLE ECUADOR	UCC	D	1	2	18.38	ANGEL	S	8/3/97 9:55	ANGEL	S	8/4/97 16:55	31.00	Y	Y	34	1.85	38	2.07	20650
EMPRESS DRAGON	UCC	D	1	2	21.21	QUEEN	N	8/3/97 16:30	QUEEN	N	8/5/97 17:15	48.75	Y	Y	40	1.89	39	1.84	42100
EVER GLOWING	UCC	D	1	2	18.88	ANGEL	N	8/7/97 17:20	ANGEL	S	8/8/97 18:35	6.65	Y	No	40	2.12	38	2.01	23180
EVER GRADE	UCC	D	1	2	18.66	ANGEL	N	8/2/97 7:35	ANGEL	N	8/4/97 5:05	29.08	No	Y	40	2.14	39	2.09	21600
EVER RACER	UCC	D	1	2	21.11	ANGEL	S	8/7/97 5:10	ANGEL	S	8/8/97 6:00	18.82	Y	No	34	1.61	38	1.80	42120
EVER UNION	UCC	D	1	2	20.42	ANGEL	N	8/2/97 15:10	ANGEL	N	8/4/97 20:30	44.50	No	Y	40	1.96	39	1.91	59510
GEORGE WASHINGTON BRIDGE	UCC	D	1	2	20.40	QUEEN	N	8/4/97 17:35	QUEEN	N	8/7/97 15:50	70.25	Y	Y	40	1.96	39	1.91	28645
HANJIN LONDON	UCC	D	1	2	23.66	QUEEN	N	8/7/97 22:35	QUEEN	N	8/10/97 14:50	1.40	Y	No	40	1.69	39	1.65	74494
HANJIN PARIS	UCC	D	1	2	21.97	QUEEN	N	8/1/97 3:25	QUEEN	N	8/3/97 13:55	13.92	No	Y	40	1.82	39	1.78	74494
HYUNDAI DYNASTY	UCC	D	1	2	19.57	QUEEN	N	8/5/97 2:20	QUEEN	N	8/6/97 23:45	45.42	Y	Y	40	2.04	39	1.99	32560
HYUNDAI FREEDOM	UCC	D	1	2	24.10	QUEEN	N	8/7/97 19:30	QUEEN	N	8/10/97 14:40	4.48	Y	No	40	1.66	39	1.62	74419
HYUNDAI INDEPENDENCE	UCC	D	1	2	23.46	QUEEN	N	7/31/97 15:20	QUEEN	N	8/3/97 15:20	15.33	No	Y	40	1.71	39	1.66	74520

Table B-1

Activity Data and NOx Marine Vessel Inventory for the August 3-7, 1997 Episode

													Cruise						
Ship Name	Vessel type	Engine Type	# Eng.	Cycle	Actual Avg./Corrected speed	Arrive Gate	Arrive Dir	Arrive Date, Time	Depart Gate	Dept. Dir	Depart Date, Time	Aug 3-7th only-Hrs at Port	Entry Cruise for 3,4,5,6,7 (Y/N)	Exit Cruise for 3,4,5,6,7 (Y/N)	Entry Cruise Dist. (nmiles)	Entry Cruise Time (hours)	Exit Cruise Dist. (nmiles)	Exit Cruise Time (hours)	Actual HP Llyods
LUTJENBURG	UCC	D	1	2	20.48	QUEEN	N	8/1/97 6:10	QUEEN	W	8/3/97 6:45	6.75	No	Y	40	1.95	43.5	2.12	36353
MAGLEBY MAERSK	UCC	D	1	2	23.73	QUEEN	S	8/6/97 21:00	QUEEN	N	8/7/97 19:35	22.58	Y	Y	34	1.43	39	1.64	57677
MARE CASPIUM	UCC	D	1	2	20.60	QUEEN	N	8/4/97 5:45	QUEEN	N	8/5/97 20:40	38.92	Y	Y	40	1.94	39	1.89	27500
MAREN MAERSK	UCC	D	1	2	23.40	QUEEN	N	8/4/97 2:10	QUEEN	S	8/4/97 16:35	14.42	Y	Y	40	1.71	38	1.62	57677
MELBOURNE STAR	UCC	D	1	2	16.38	ANGEL	S	7/31/97 18:45	ANGEL	S	8/4/97 18:55	42.92	No	Y	34	2.08	38	2.32	17100
MING PLENTY	UCC	D	1	2	19.10	ANGEL	N	8/4/97 13:30	ANGEL	N	8/7/97 7:10	65.67	Y	Y	40	2.09	39	2.04	23690
MOKIHANA	UCC	D	1	2	22.70	ANGEL	N	8/4/97 6:05	ANGEL	N	8/5/97 22:10	40.08	Y	Y	40	1.76	39	1.72	43200
N O L RUBY	UCC	D	1	2	21.48	ANGEL	N	8/2/97 20:40	ANGEL	N	8/4/97 18:00	42.00	No	Y	40	1.86	39	1.82	38070
N O L ZIRCON	UCC	D	1	2	21.48	ANGEL	N	7/31/97 18:10	ANGEL	N	8/6/97 3:40	75.67	No	Y	40	1.86	39	1.82	38070
NEPTUNE JADE	UCC	D	1	2	17.75	ANGEL	N	8/7/97 6:25	QUEEN	S	8/7/97 18:55	12.50	Y	Y	40	2.25	38	2.14	31479
NYK SEABREEZE	UCC	D	1	2	18.94	ANGEL	N	8/1/97 23:30	ANGEL	N	8/3/97 20:10	20.17	No	Y	40	2.11	39	2.06	40500
OOCL AMERICA	UCC	D	1	2	15.10	QUEEN	N	8/2/97 6:10	QUEEN	N	8/6/97 5:30	77.50	No	Y	40	2.65	39	2.58	66120
SEA-LAND CHARGER	UCC	D	1	2	21.84	QUEEN	N	8/1/97 6:30	QUEEN	N	8/4/97 2:25	26.42	No	Y	40	1.83	39	1.79	49589
SEA-LAND GUATEMALA	UCC	D	1	4	16.58	QUEEN	S	8/7/97 5:15	QUEEN	S	8/7/97 21:30	16.25	Y	Y	34	2.05	38	2.29	11968
SEA-LAND PATRIOT	UCC	D	1	2	17.10	QUEEN	N	8/4/97 18:20	QUEEN	N	8/7/97 5:15	58.92	Y	Y	40	2.34	39	2.28	30150
SOVCOMFLOT SENATOR	UCC	D	1	2	19.11	QUEEN	S	8/3/97 6:10	QUEEN	N	8/4/97 12:10	30.00	Y	Y	34	1.78	39	2.04	29470
VLADIVOSTOK SENATOR	UCC	D	1	2	22.75	QUEEN	N	8/5/97 6:05	QUEEN	S	8/6/97 16:50	34.75	Y	Y	40	1.76	38	1.67	29501
YURIY OSTROVSKIY	UCC	D	1	2	17.54	QUEEN	N	8/2/97 6:20	QUEEN	S	8/3/97 2:00	2.00	No	Y	40	2.28	38	2.17	9421
ZIM AMERICA	UCC	D	1	2	19.11	QUEEN	S	8/2/97 5:35	QUEEN	N	8/3/97 18:05	18.08	No	Y	34	1.78	39	2.04	29440
ZIM CANADA	UCC	D	1	2	17.32	QUEEN	N	8/7/97 16:15	QUEEN	S	8/8/97 17:15	7.73	Y	No	40	2.31	38	2.19	29440
CHEVRON COLORADO	TTA	GT	1		14.10	QUEEN	S	8/3/97 16:00	QUEEN	W	8/5/97 5:05	37.08	Y	Y	34	2.41	43.5	3.09	12500
CHEVRON OREGON	TTA	GT	1		12.91	QUEEN	S	8/6/97 17:20	QUEEN	W	8/6/97 19:00	1.67	Y	Y	34	2.63	43.5	3.37	12500
																Entry Cruise Time (hours)		Exit Cruise Time (hours)	RFC @ Full (80%) Power (gal/hr)
ARCO INDEPENDENCE	TTA	ST	2		13.09	QUEEN	W	8/6/97 23:30	QUEEN	W	8/8/97 21:45	24.48	Y	No	43.5	3.32	43.5	3.32	2093.4
ARCO PRUDHOE BAY	TTA	ST	2		15.90	QUEEN	W	7/28/97 13:10	QUEEN	S	8/4/97 20:35	44.58	No	Y	43.5	2.74	38	2.39	1238.6
ARCO SAG RIVER	TTA	ST	2		14.24	QUEEN	W	8/5/97 21:20	QUEEN	W	8/7/97 22:20	49.00	Y	No	43.5	3.05	43.5	3.05	1128.1
ARCO SPIRIT	TTA	ST	2		13.91	QUEEN	W	7/30/97 16:45	QUEEN	N	8/3/97 18:00	18.00	No	Y	43.5	3.13	39	2.80	2093.4
BLUE RIDGE	TTA	ST	2		13.80	ANGEL	S	8/5/97 13:45	ANGEL	S	8/13/97 2.50	58.23	Y	No	34	2.46	38	2.75	793.8
FREDERICKSBURG	TTA	ST	2		15.77	ANGEL	W	8/5/97 20:00	ANGEL	W	8/7/97 21:05	49.08	Y	Y	43.5	2.76	43.5	2.76	1238.6
MARINE CHEMIST	TTA	ST	2		15.87	ANGEL	W	8/7/97 1:30	ANGEL	S	8/8/97 18:20	22.48	Y	No	43.5	2.74	38	2.39	1017.6
EWA	UCC	ST	2		19.34	ANGEL	N	8/3/97 5:05	ANGEL	N	8/4/97 1:20	20.25	Y	Y	40	2.07	39	2.02	1604.9
KAUAI	UCC	ST	2		18.20	ANGEL	N	8/4/97 4:30	ANGEL	W	8/6/97 16:15	59.75	Y	Y	40	2.20	66	3.63	1279.3
SEA-LAND CHALLENGER	UCC	ST	2		18.30	QUEEN	N	8/7/97 6:10	QUEEN	W	8/9/97 4:40	17.82	Y	No	40	2.19	66	3.61	909.4
MATSONIA	URC	ST	2		20.59	ANGEL	W	8/6/97 15:30	ANGEL	W	8/9/97 5:35	32.48	Y	No	66	3.21	66	3.21	989.3

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Table B-1

Activity Data and NOx Marine Vessel Inventory for the August 3-7, 1997 Episode

		Cruise											Precautionary Zone Cruise (PZC)				
Ship Name	Cruise 80% MCR Power	Entry Cruise hp-hr	Exit Cruise hp-hr	Entry Cruise kWh	Exit Cruise kWh	NOx EMSFAC Cruise (g/kWh) or (lb/1000 gal)	Entry Cruise NOx (g)	Exit Cruise NOx (g)	Entry Cruise NOx (lbs.)	Exit Cruise NOx (lbs.)	Entry Cruise NOx (tons)	Exit Cruise NOx (tons)	Entry PZC (Y/N)	Exit PZC (Y/N)	Entry PZC Dist (nmiles)	Entry PZC Time (hours)	Exit PZC Dist (nmiles)
BEL ACE	8880	24231	27795	17822	20443	17.32	308677	354071	680	780	0.34	0.39	Y	Y	6.5	0.54	6
FARENCO	15543	45098	43971	33170	32340	17.32	574499	560137	1265	1234	0.63	0.62	Y	No	8	0.67	6
FIVI	9280	25746	25102	18936	18462	17.32	327970	319770	722	704	0.36	0.35	No	No	4.5	0.38	3.5
MODI	10480	31401	29831	23095	21940	17.32	400010	380009	881	837	0.44	0.42	Y	Y	8	0.67	6
NOSHIRO MARU	8856	28430	27719	20910	20388	17.32	362168	353114	798	778	0.40	0.39	No	Y	4.5	0.38	3.5
OTRADA	10656	27058	25705	19901	18906	17.32	344684	327450	759	721	0.38	0.36	No	Y	4.5	0.38	3.5
PERICLES C.G.	13920	40362	38344	29687	28202	17.32	514172	488463	1133	1076	0.57	0.54	No	Y	8	0.67	6
SAGACIOUS NIKE	7800	22609	22043	16629	16213	17.32	288009	280809	634	619	0.32	0.31	Y	No	8	0.67	6
SINGAPORE ACE	12640	42395	41335	31181	30402	17.32	540061	526559	1190	1160	0.59	0.58	Y	No	8	0.67	6
PACPRINCE	7600	23313	22147	17147	16289	17.32	296980	282131	654	621	0.33	0.31	Y	Y	8	0.67	6
PACPRINCESS	7600	18976	21767	13957	16010	17.32	241736	277286	532	611	0.27	0.31	Y	No	6.5	0.54	6
STAR DROTTANGER	10480	26691	29831	19631	21940	17.32	340008	380009	749	837	0.37	0.42	Y	Y	7.5	0.63	6
KARINA BONITA	8960	23443	22271	17242	16380	17.32	298640	283708	658	625	0.33	0.31	Y	Y	8	0.67	6
STAR GRIP	8096	21900	20805	16107	15302	17.32	278976	265027	614	584	0.31	0.29	Y	Y	4.5	0.38	3.5
VAIMAMA	6472	15831	18159	11644	13356	12.81	149154	171088	329	377	0.16	0.19	Y	Y	6.5	0.54	6
CHIQUITA FRANCES	12970	24230	27081	17821	19918	12.81	228293	255151	503	562	0.25	0.28	Y	No	6.5	0.54	6
MAGIC	7150	13356	14928	9824	10979	12.81	125841	140645	277	310	0.14	0.15	Y	Y	6.5	0.54	6
TUNDRA KING	10600	23297	22132	17135	16278	17.32	296773	281935	654	621	0.33	0.31	Y	Y	4.5	0.38	3.5
HOLIDAY	25578	74330	83075	54670	61102	17.32	946884	1058283	2086	2331	1.04	1.17	Y	Y	7.5	0.63	6
JUBILEE	25570	68293	76327	50229	56139	17.32	869971	972321	1916	2142	0.96	1.07	Y	Y	7.5	0.63	6
VIKING SERENADE	21600	66764	74618	49105	54882	17.32	850493	950551	1873	2094	0.94	1.05	Y	Y	7.5	0.63	6
AYA II	13504	28030	32152	20616	23648	12.81	264094	302932	582	667	0.29	0.33	Y	Y	7.5	0.63	6
BELLONA	9248	22584	22019	16610	16195	17.32	287690	280498	634	618	0.32	0.31	Y	Y	8	0.67	6
FRANCONIA	9984	21075	24174	15501	17780	17.32	268472	307953	591	678	0.30	0.34	Y	No	6.5	0.54	6
GREEN LAKE	10495	25278	24646	18592	18127	17.32	322016	313965	709	692	0.35	0.35	Y	Y	8	0.67	6
HUAL CARMENCITA	1040	2492	2429	1833	1787	17.32	31742	30949	70	68	0.03	0.03	Y	Y	4.5	0.38	3.5
OPAL RAY	9920	24091	23489	17719	17276	17.32	306890	299217	676	659	0.34	0.33	Y	No	4.5	0.38	3.5
STOLT TENACITY	13920	40021	34961	29436	25714	17.32	509824	445363	1123	981	0.56	0.49	Y	No	8	0.67	6
BT NESTOR	13439	31116	34776	22886	25578	17.32	396377	443010	873	976	0.44	0.49	No	Y	6.5	0.54	6
SAMUEL GINN	15120	50304	45100	36998	33171	17.32	640811	574520	1411	1265	0.71	0.63	Y	No	8	0.67	6
ACAPULCO	24793	42106	48298	30969	35523	17.32	536378	615257	1181	1355	0.59	0.68	Y	Y	7.5	0.63	6
ALLIGATOR BRAVERY	37568	69951	68202	51449	50163	17.32	891095	868817	1963	1914	0.98	0.96	Y	Y	4.5	0.38	3.5
APL SINGAPORE	53118	88163	85959	64844	63223	17.32	1123100	1095023	2474	2412	1.24	1.21	No	Y	4.5	0.38	3.5
AXEL MAERSK	36640	66552	64888	48949	47725	17.32	847792	826597	1867	1821	0.93	0.91	No	Y	8	0.67	6
BRISBANE STAR	23200	49745	48502	36588	35673	17.32	633699	617857	1396	1361	0.70	0.68	Y	No	4.5	0.38	3.5
BROOKLYN BRIDGE	29952	61860	60314	45498	44361	17.32	788030	768329	1736	1692	0.87	0.85	No	Y	8	0.67	6
CALIFORNIA JUPITER	23616	47185	46005	34704	33837	17.32	601081	586054	1324	1291	0.66	0.65	Y	No	4.5	0.38	3.5
CALIFORNIA SATURN	23688	40229	46145	29589	33940	17.32	512476	587840	1129	1295	0.56	0.65	Y	No	7.5	0.63	6
CAPE CHARLES	26240	44563	51117	32776	37596	17.32	567687	651171	1250	1434	0.63	0.72	No	Y	7.5	0.63	6
CHASTINE MAERSK	11398	23020	25728	16931	18923	17.32	293252	327752	646	722	0.32	0.36	Y	No	6.5	0.54	6
CHETUMAL	30834	57673	54790	42419	40298	17.32	734692	697958	1618	1537	0.81	0.77	Y	Y	4.5	0.38	3.5
DIRECT EAGLE	18239	42702	40567	31408	29837	12.81	402330	382214	886	842	0.44	0.42	Y	No	4.5	0.38	3.5
DOLE ECUADOR	16520	30568	34164	22482	25127	17.32	389397	435208	858	959	0.43	0.48	Y	Y	7.5	0.63	6
EMPRESS DRAGON	33680	63511	61923	46712	45544	17.32	809057	788830	1782	1738	0.89	0.87	Y	Y	8	0.67	6
EVER GLOWING	18544	39283	37319	28893	27448	17.32	500420	475399	1102	1047	0.55	0.52	Y	No	4.5	0.38	3.5
EVER GRADE	17280	37052	36125	27252	26570	17.32	471997	460197	1040	1014	0.52	0.51	No	Y	4.5	0.38	3.5
EVER RACER	33696	54266	60650	39913	44608	17.32	691287	772615	1523	1702	0.76	0.85	Y	No	7.5	0.63	6
EVER UNION	47608	93269	90937	68599	66884	17.32	1188141	1158437	2617	2552	1.31	1.28	No	Y	4.5	0.38	3.5
GEORGE WASHINGTON BRIDGE	22916	44933	43810	33048	32222	17.32	572399	558089	1261	1229	0.63	0.61	Y	Y	8	0.67	6
HANJIN LONDON	59595	100753	98234	74104	72251	17.32	1283474	1251387	2827	2756	1.41	1.38	Y	No	8	0.67	6
HANJIN PARIS	59595	108528	105814	79822	77826	17.32	1382517	1347955	3045	2969	1.52	1.48	No	Y	8	0.67	6
HYUNDAI DYNASTY	26048	53254	51923	39169	38189	17.32	678399	661439	1494	1457	0.75	0.73	Y	Y	8	0.67	6
HYUNDAI FREEDOM	59535	98824	96353	72685	70868	17.32	1258903	1227431	2773	2704	1.39	1.35	Y	No	8	0.67	6
HYUNDAI INDEPENDENCE	59616	101647	99106	74761	72892	17.32	1294868	1262496	2852	2781	1.43	1.39	No	Y	8	0.67	6

Table B-1

Activity Data and NOx Marine Vessel Inventory for the August 3-7, 1997 Episode

		Cruise												Precautionary Zone Cruise (PZC)				
Ship Name	Cruise 80% MCR Power	Entry Cruise hp-hr	Exit Cruise hp-hr	Entry Cruise kWh	Exit Cruise kWh	NOx EMSFAC Cruise (g/kWh) or (lb/1000 gal)	Entry Cruise NOx (g)	Exit Cruise NOx (g)	Entry Cruise NOx (lbs.)	Exit Cruise NOx (lbs.)	Entry Cruise NOx (tons)	Exit Cruise NOx (tons)	Entry PZC (Y/N)	Exit PZC (Y/N)	Entry PZC Dist (nmiles)	Entry PZC Time (hours)	Exit PZC Dist (nmiles)
LUTJENBURG	29082	56815	61787	41788	45444	17.32	723764	787093	1594	1734	0.80	0.87	No	Y	8	0.67	6
MAGLEBY MAERSK	46142	66104	75825	48620	55769	17.32	842090	965927	1855	2128	0.93	1.06	Y	Y	6.5	0.54	6
MARE CASPIUM	22000	42718	41650	31419	30634	17.32	544184	530580	1199	1169	0.60	0.58	Y	Y	8	0.67	6
MAREN MAERSK	46142	78875	74931	58012	55112	17.32	1004772	954533	2213	2102	1.11	1.05	Y	Y	8	0.67	6
MELBOURNE STAR	13680	28396	31736	20885	23342	17.32	361728	404284	797	890	0.40	0.45	No	Y	7.5	0.63	6
MING PLENTY	18952	39690	38698	29192	28462	17.32	505606	492966	1114	1086	0.56	0.54	Y	Y	4.5	0.38	3.5
MOKIHANA	34560	60899	59376	44791	43671	17.32	775780	756385	1709	1666	0.85	0.83	Y	Y	4.5	0.38	3.5
N O L RUBY	30456	56726	55308	41722	40679	17.32	722620	704555	1592	1552	0.80	0.78	No	Y	4.5	0.38	3.5
N O L ZIRCON	30456	56726	55308	41722	40679	17.32	722620	704555	1592	1552	0.80	0.78	No	Y	4.5	0.38	3.5
NEPTUNE JADE	25183	56767	53929	41752	39664	17.32	723145	686988	1593	1513	0.80	0.76	Y	Y	4.5	0.38	3.5
NYK SEABREEZE	32400	68418	66707	50321	49063	17.32	871562	849773	1920	1872	0.96	0.94	No	Y	4.5	0.38	3.5
OOCL AMERICA	52896	140122	136619	103060	100483	17.32	1784993	1740368	3932	3833	1.97	1.92	No	Y	8	0.67	6
SEA-LAND CHARGER	39671	72658	70841	53440	52104	17.32	925579	902439	2039	1988	1.02	0.99	No	Y	8	0.67	6
SEA-LAND GUATEMALA	9574	19638	21948	14444	16143	12.81	185023	206790	408	455	0.20	0.23	Y	Y	6.5	0.54	6
SEA-LAND PATRIOT	24120	56421	55011	41498	40460	17.32	718740	700771	1583	1544	0.79	0.77	Y	Y	8	0.67	6
SOVCOMFLOT SENATOR	23576	41946	48114	30851	35388	17.32	534342	612921	1177	1350	0.59	0.68	Y	Y	6.5	0.54	6
VLADIVOSTOK SENATOR	23601	41496	39421	30520	28994	17.32	528611	502180	1164	1106	0.58	0.55	Y	Y	8	0.67	6
YURIY OSTROVSKIY	7537	17193	16333	12645	12013	17.32	219014	208063	482	458	0.24	0.23	No	Y	8	0.67	6
ZIM AMERICA	23552	41903	48065	30820	35352	17.32	533798	612297	1176	1349	0.59	0.67	No	Y	6.5	0.54	6
ZIM CANADA	23552	54393	51673	40006	38005	17.32	692900	658255	1526	1450	0.76	0.72	Y	No	8	0.67	6
CHEVRON COLORADO	10000	24113	30851	17735	22691	8.58	152170	194688	335	429	0.17	0.21	Y	Y	6.5	0.54	6
CHEVRON OREGON	10000	26346	33708	19378	24792	8.58	166261	212717	366	469	0.18	0.23	Y	Y	6.5	0.54	6
		Entry Cruise FC (gals)	Exit Cruise FC (gals)			Cruise Ems Factors (lb/ 1000gal)			Entry Cruise NOx (lbs.)	Exit Cruise NOx (lbs.)	Entry Cruise NOx (tons)	Exit Cruise NOx (tons)					
ARCO INDEPENDENCE		6959	6959			55.8			388	388	0.19	0.19	Y	No	8	0.67	6
ARCO PRUDHOE BAY		3389	2960			55.8			189	165	0.09	0.08	No	Y	8	0.67	6
ARCO SAG RIVER		3446	3446			55.8			192	192	0.10	0.10	Y	No	8	0.67	6
ARCO SPIRIT		6548	5870			55.8			365	328	0.18	0.16	No	Y	8	0.67	6
BLUE RIDGE		1956	2187			55.8			109	122	0.05	0.06	Y	No	7.5	0.63	6
FREDERICKSBURG		3417	3417			55.8			191	191	0.10	0.10	Y	Y	4.5	0.38	3.5
MARINE CHEMIST		2789	2437			55.8			156	136	0.08	0.07	Y	No	4.5	0.38	3.5
EWA		3320	3237			55.8			185	181	0.09	0.09	Y	Y	4.5	0.38	3.5
KAUAI		2812	4639			55.8			157	259	0.08	0.13	Y	Y	4.5	0.38	3.5
SEA-LAND CHALLENGER		1988	3280			55.8			111	183	0.06	0.09	Y	No	8	0.67	6
MATSONIA		3171	3171			55.8			177	177	0.09	0.09	Y	No	4.5	0.38	3.5

Table B-1

Activity Data and NOx Marine Vessel Inventory for the August 3-7, 1997 Episode

			Precautionary Zone Cruise (PZC)														
Ship Name	Exit PZC Time (hours)	PZC 12 Kts/Design Speed	PZC Speed Ratio Cubed	PZC % MCR @ 12 Kts	Actual HP Llyods	PZC Power (bhp)	Entry PZC hp-hr	Exit PZC hp-hr	Entry PZC (kWh)	Exit PZC (kWh)	NOx EMSFAC PZC (g/kWh)	Entry PZC NOx (g)	Exit PZC NOx (g)	Entry PZC NOx (lbs.)	Exit PZC NOx (lbs.)	Entry PZC NOx (tons)	Exit PZC NOx (tons)
BEL ACE	0.50	96%	89%	71	11100	7932	4297	3966	3160	2917	17.48	55247	50997	122	112	0.06	0.06
FARENCO	0.50	87%	66%	53	19429	10251	6834	5125	5026	3770	17.81	89499	67124	197	148	0.10	0.07
FIVI	0.29	83%	58%	46	11600	5350	2006	1560	1476	1148	17.93	26462	20581	58	45	0.03	0.02
MODI	0.50	90%	73%	58	13100	7611	5074	3806	3732	2799	17.72	66118	49588	146	109	0.07	0.05
NOSHIRO MARU	0.29	96%	89%	71	11070	7911	2967	2307	2182	1697	17.48	38145	29668	84	65	0.04	0.03
OTRADA	0.29	76%	44%	35	13320	4710	1766	1374	1299	1010	18.13	23554	18320	52	40	0.03	0.02
PERICLES C.G.	0.50	87%	66%	53	17400	9163	6108	4581	4493	3370	17.81	79997	59998	176	132	0.09	0.07
SAGACIOUS NIKE	0.50	87%	66%	53	9750	5129	3419	2564	2515	1886	17.81	44777	33583	99	74	0.05	0.04
SINGAPORE ACE	0.50	101%	102%	81	15800	12877	8585	6438	6314	4735	17.30	109243	81932	241	180	0.12	0.09
PACPRINCE	0.50	92%	78%	62	9500	5923	3949	2961	2904	2178	17.64	51240	38430	113	85	0.06	0.04
PACPRINCESS	0.50	88%	68%	55	9500	5201	2817	2601	2072	1913	17.77	36823	33990	81	75	0.04	0.04
STAR DROTTANGER	0.50	90%	73%	58	13100	7611	4757	3806	3499	2799	17.72	61985	49588	137	109	0.07	0.05
KARINA BONITA	0.50	78%	48%	39	11200	4333	2889	2167	2125	1594	18.06	38367	28775	85	63	0.04	0.03
STAR GRIP	0.29	81%	53%	43	10120	4326	1622	1262	1193	928	17.99	21462	16693	47	37	0.02	0.02
VAIMAMA	0.50	86%	64%	51	8090	4164	2256	2082	1659	1531	13.69	22719	20971	50	46	0.03	0.02
CHIQUITA FRANCES	0.50	66%	29%	23	16213	3718	2014	1859	1481	1367	14.55	21548	19890	47	44	0.02	0.02
MAGIC	0.50	66%	29%	23	8937	2049	1110	1025	816	754	14.55	11878	10964	26	24	0.01	0.01
TUNDRA KING	0.29	66%	29%	23	13250	3038	1139	886	838	652	18.35	15381	11963	34	26	0.02	0.01
HOLIDAY	0.50	103%	108%	86	31973	27597	17248	13798	12686	10149	17.21	218350	174680	481	385	0.24	0.19
JUBILEE	0.50	94%	84%	67	31962	21418	13386	10709	9846	7877	17.55	172831	138265	381	305	0.19	0.15
VIKING SERENADE	0.50	109%	130%	104	27000	28043	17527	14021	12891	10313	16.89	217701	174161	480	384	0.24	0.19
AYA II	0.50	73%	39%	31	16880	5310	3319	2655	2441	1953	14.30	34908	27926	77	62	0.04	0.03
BELLONA	0.50	73%	39%	31	11560	3636	2424	1818	1783	1337	18.20	32457	24343	71	54	0.04	0.03
FRANCONIA	0.50	75%	41%	33	12480	4129	2236	2064	1645	1518	18.17	29881	27583	66	61	0.03	0.03
GREEN LAKE	0.50	72%	38%	30	13119	3959	2640	1980	1941	1456	18.22	35378	26533	78	58	0.04	0.03
HUAL CARMENCITA	0.29	72%	37%	30	1300	386	145	113	107	83	18.22	1941	1510	4	3	0.00	0.00
OPAL RAY	0.29	73%	39%	31	12400	3836	1439	1119	1058	823	18.20	19262	14981	42	33	0.02	0.02
STOLT TENACITY	0.50	79%	50%	40	17400	6945	4630	3472	3405	2554	18.04	61432	46074	135	101	0.07	0.05
BT NESTOR	0.50	82%	55%	44	16799	7333	3972	3667	2922	2697	17.97	52494	48456	116	107	0.06	0.05
SAMUEL GINN	0.50	92%	77%	62	18900	11689	7793	5844	5731	4299	17.64	101125	75844	223	167	0.11	0.08
ACAPULCO	0.50	60%	22%	17	30991	5339	3337	2670	2454	1963	18.46	45317	36254	100	80	0.05	0.04
ALLIGATOR BRAVERY	0.29	56%	17%	14	46960	6548	2455	1910	1806	1405	18.52	33444	26012	74	57	0.04	0.03
APL SINGAPORE	0.29	50%	12%	10	66398	6557	2459	1913	1809	1407	18.59	33623	26151	74	58	0.04	0.03
AXEL MAERSK	0.50	54%	16%	13	45800	5928	3952	2964	2907	2180	18.54	53881	40411	119	89	0.06	0.04
BRISBANE STAR	0.29	64%	27%	21	29000	6175	2316	1801	1703	1325	18.39	31323	24362	69	54	0.03	0.03
BROOKLYN BRIDGE	0.50	62%	24%	19	37440	7124	4750	3562	3493	2620	18.43	64375	48281	142	106	0.07	0.05
CALIFORNIA JUPITER	0.29	60%	22%	17	29520	5086	1907	1483	1403	1091	18.46	25900	20144	57	44	0.03	0.02
CALIFORNIA SATURN	0.50	60%	22%	17	29610	5101	3188	2551	2345	1876	18.46	43298	34638	95	76	0.05	0.04
CAPE CHARLES	0.50	60%	22%	17	32800	5651	3532	2825	2598	2078	18.46	47963	38370	106	85	0.05	0.04
CHASTINE MAERSK	0.50	71%	36%	29	14248	4128	2236	2064	1645	1518	18.24	30001	27693	66	61	0.03	0.03
CHETUMAL	0.29	56%	18%	14	38542	5448	2043	1589	1503	1169	18.52	27826	21642	61	48	0.03	0.02
DIRECT EAGLE	0.29	70%	35%	28	22799	6320	2370	1843	1743	1356	14.39	25090	19514	55	43	0.03	0.02
DOLE ECUADOR	0.50	65%	28%	22	20650	4601	2876	2301	2115	1692	18.37	38859	31087	86	68	0.04	0.03
EMPRESS DRAGON	0.50	57%	18%	14	42100	6098	4065	3049	2990	2242	18.52	55367	41525	122	91	0.06	0.05
EVER GLOWING	0.29	64%	26%	21	23180	4760	1785	1388	1313	1021	18.39	24143	18778	53	41	0.03	0.02
EVER GRADE	0.29	64%	27%	21	21600	4599	1725	1341	1269	987	18.39	23330	18146	51	40	0.03	0.02
EVER RACER	0.50	57%	18%	15	42120	6188	3867	3094	2844	2276	18.50	52622	42098	116	93	0.06	0.05
EVER UNION	0.29	59%	20%	16	59510	9665	3624	2819	2666	2073	18.48	49270	38321	109	84	0.05	0.04
GEORGE WASHINGTON BRIDGE	0.50	59%	20%	16	28645	4664	3110	2332	2287	1715	18.48	42270	31703	93	70	0.05	0.03
HANJIN LONDON	0.50	51%	13%	10	74494	7775	5183	3888	3812	2859	18.59	70873	53155	156	117	0.08	0.06
HANJIN PARIS	0.50	55%	16%	13	74494	9718	6478	4859	4765	3574	18.54	88322	66241	195	146	0.10	0.07
HYUNDAI DYNASTY	0.50	61%	23%	18	32560	6010	4007	3005	2947	2210	18.45	54359	40769	120	90	0.06	0.04
HYUNDAI FREEDOM	0.50	50%	12%	10	74419	7352	4901	3676	3605	2704	18.59	67015	50261	148	111	0.07	0.06
HYUNDAI INDEPENDENCE	0.50	51%	13%	11	74520	7979	5319	3989	3912	2934	18.57	72656	54492	160	120	0.08	0.06

Table B-1

Activity Data and NOx Marine Vessel Inventory for the August 3-7, 1997 Episode

			Precautionary Zone Cruise (PZC)														
Ship Name	Exit PZC Time (hours)	PZC 12 Kts/Design Speed	PZC Speed Ratio Cubed	PZC % MCR @ 12 Kts	Actual HP Llyods	PZC Power (bhp)	Entry PZC hp-hr	Exit PZC hp-hr	Entry PZC (kWh)	Exit PZC (kWh)	NOx EMSFAC PZC (g/kWh)	Entry PZC NOx (g)	Exit PZC NOx (g)	Entry PZC NOx (lbs.)	Exit PZC NOx (lbs.)	Entry PZC NOx (tons)	Exit PZC NOx (tons)
LUTJENBURG	0.50	59%	20%	16	36353	5855	3903	2927	2871	2153	18.48	53057	39793	117	88	0.06	0.04
MAGLEBY MAERSK	0.50	51%	13%	10	57677	5965	3231	2982	2376	2194	18.59	44177	40779	97	90	0.05	0.04
MARE CASPIUM	0.50	58%	20%	16	27500	4349	2899	2174	2132	1599	18.48	39410	29557	87	65	0.04	0.03
MAREN MAERSK	0.50	51%	13%	11	57677	6223	4149	3111	3051	2288	18.57	56668	42501	125	94	0.06	0.05
MELBOURNE STAR	0.50	73%	39%	31	17100	5379	3362	2689	2473	1978	18.20	45011	36009	99	79	0.05	0.04
MING PLENTY	0.29	63%	25%	20	23690	4700	1763	1371	1296	1008	18.22	23623	18373	52	40	0.03	0.02
MOKIHANA	0.29	53%	15%	12	43200	5106	1915	1489	1408	1095	18.55	26127	20321	58	45	0.03	0.02
N O L RUBY	0.29	56%	17%	14	38070	5313	1992	1550	1465	1140	18.52	27137	21107	60	46	0.03	0.02
N O L ZIRCON	0.29	56%	17%	14	38070	5313	1992	1550	1465	1140	18.52	27137	21107	60	46	0.03	0.02
NEPTUNE JADE	0.29	68%	31%	25	31479	7788	2921	2272	2148	1671	18.32	39343	30600	87	67	0.04	0.03
NYK SEABREEZE	0.29	63%	25%	20	40500	8237	3089	2403	2272	1767	18.41	41826	32531	92	72	0.05	0.04
OOCL AMERICA	0.50	79%	50%	40	66120	26548	17699	13274	13017	9763	18.04	234835	176127	517	388	0.26	0.19
SEA-LAND CHARGER	0.50	55%	17%	13	49589	6581	4387	3290	3227	2420	18.54	59809	44857	132	99	0.07	0.05
SEA-LAND GUATEMALA	0.50	72%	38%	30	11968	3632	1967	1816	1447	1336	14.33	20740	19145	46	42	0.02	0.02
SEA-LAND PATRIOT	0.50	70%	35%	28	30150	8336	5557	4168	4087	3065	18.26	74632	55974	164	123	0.08	0.06
SOVCOMFLOT SENATOR	0.50	63%	25%	20	29470	5838	3162	2919	2326	2147	18.41	42815	39522	94	87	0.05	0.04
VLADIVOSTOK SENATOR	0.50	53%	15%	12	29501	3464	2309	1732	1698	1274	18.55	31510	23633	69	52	0.03	0.03
YURIY OSTROVSKIY	0.50	68%	32%	26	9421	2416	1610	1208	1184	888	18.30	21672	16254	48	36	0.02	0.02
ZIM AMERICA	0.50	63%	25%	20	29440	5832	3159	2916	2323	2145	18.41	42772	39482	94	87	0.05	0.04
ZIM CANADA	0.50	69%	33%	27	29440	7833	5222	3916	3841	2881	18.28	70206	52654	155	116	0.08	0.06
CHEVRON COLORADO	0.50	85%	62%	49	12500	6164	3339	3082	2456	2267	*9.43*	23159	21377	51	47	0.03	0.02
CHEVRON OREGON	0.50	93%	80%	64	12500	8040	4355	4020	3203	2957	*9.43*	30206	27883	67	61	0.03	0.03
					RFC @ Full (80%) Power (gal/hr)												
ARCO INDEPENDENCE	0.50	92%	77%	62	2093.4	1614	1076	807			55.8			60	45	0.03	0.02
ARCO PRUDHOE BAY	0.50	75%	43%	34	1238.6	532	355	266			55.8			20	15	0.01	0.01
ARCO SAG RIVER	0.50	84%	60%	48	1128.1	675	450	338			55.8			25	19	0.01	0.01
ARCO SPIRIT	0.50	86%	64%	51	2093.4	1345	896	672			55.8			50	38	0.03	0.02
BLUE RIDGE	0.50	87%	66%	53	793.8	523	327	261			55.8			18	15	0.01	0.01
FREDERICKSBURG	0.29	76%	44%	35	1238.6	546	205	159			55.8			11	9	0.0057	0.0044
MARINE CHEMIST	0.29	76%	43%	35	1017.6	440	165	128			55.8			9	7	0.0046	0.0036
EWA	0.29	62%	24%	19	1604.9	384	144	112			55.8			8	6	0.0040	0.0031
KAUAI	0.29	66%	29%	23	1279.3	367	138	107			55.8			8	6	0.0038	0.0030
SEA-LAND CHALLENGER	0.50	66%	28%	23	909.4	257	171	128			55.8			10	7	0.0048	0.0036
MATSONIA	0.29	58%	20%	16	989.3	196	73	57			55.8			4	3	0.0020	0.0016

Table B-1

Activity Data and NOx Marine Vessel Inventory for the August 3-7, 1997 Episode

	Maneuvering				Maneuvering																		
Ship Name	Entry Manvg (Y/N)	Exit Manvg (Y/N)	Entry Manvg (hrs)	Exit Manvg (hrs)	(Hrs at port-Mane) Hotelling (hrs)	Actual HP Llyods	% MCR @ 5 kts Manvg	Manvg Power (bhp)	Entry Manvg power hp-hr	Exit Manvg power hp-hr	Entry Manvg power (kWh)	Exit Manvg power (kWh)	NOx EMSFAC Manvg (g/kWh)	Entry Manvg NOx (g)	Exit Manvg NOx (g)	Entry Manvg NOx (lbs.)	Exit Manvg NOx (lbs.)	Entry Manvg NOx (tons)	Exit Manvg NOx (tons)	Aux. Entry All Cruise (Y/N)
BEL ACE	Y	Y	0.33	0.58	3.51	11100	20	2220	733	1288	539	947	18.41	9920	17435	22	38	0.01	0.02	Y
FARENCO	Y	No	0.35	2.58	102.88	19429	20	3886	1360	10025	1000	7374	18.41	18416	135749	41	299	0.02	0.15	Y
FIVI	No	No	1.67	1.50	119.98	11600	20	2320	3867	3480	2844	2560	18.41	52357	47121	115	104	0.06	0.05	No
MODI	Y	Y	0.42	0.38	10.70	13100	20	2620	1092	1004	803	739	18.41	14782	13599	33	30	0.02	0.01	Y
NOSHIRO MARU	No	Y	0.92	0.50	89.33	11070	20	2214	2030	1107	1493	814	18.41	27481	14989	61	33	0.03	0.02	No
OTRADA	No	Y	1.17	0.75	13.50	13320	20	2664	3108	1998	2286	1470	18.41	42084	27054	93	60	0.05	0.03	No
PERICLES C.G.	No	Y	1.25	0.73	18.85	17400	20	3480	4350	2552	3199	1877	18.41	58901	34555	130	76	0.06	0.04	No
SAGACIOUS NIKE	Y	No	0.72	1.25	80.02	9750	20	1950	1398	2438	1028	1793	18.41	18923	33005	42	73	0.02	0.04	Y
SINGAPORE ACE	Y	No	0.50	1.25	45.90	15800	20	3160	1580	3950	1162	2905	18.41	21394	53485	47	118	0.02	0.06	Y
PACPRINCE	Y	Y	0.50	1.25	19.83	9500	20	1900	950	2375	699	1747	18.41	12864	32159	28	71	0.01	0.04	Y
PACPRINCESS	Y	No	1.25	1.25	33.07	9500	20	1900	2375	2375	1747	1747	18.41	32159	32159	71	71	0.04	0.04	Y
STAR DROTTANGER	Y	Y	1.33	0.67	38.50	13100	20	2620	3493	1747	2569	1285	18.41	47302	23651	104	52	0.05	0.03	Y
KARINA BONITA	Y	Y	0.42	0.93	42.48	11200	20	2240	933	2091	686	1538	18.41	12638	28309	28	62	0.01	0.03	Y
STAR GRIP	Y	Y	1.17	0.67	6.42	10120	20	2024	2361	1349	1737	992	18.41	31974	18271	70	40	0.04	0.02	Y
VAIMAMA	Y	Y	0.83	0.42	18.58	8090	20	1618	1348	674	992	496	14.64	14518	7259	32	16	0.02	0.01	Y
CHIQUITA FRANCES	Y	No	1.58	0.50	18.48	16213	15	2432	3851	1216	2832	894	14.79	41887	13227	92	29	0.05	0.01	Y
MAGIC	Y	Y	0.88	0.90	19.38	8937	15	1341	1184	1206	871	887	14.79	12881	13124	28	29	0.01	0.01	Y
TUNDRA KING	Y	Y	0.67	0.58	11.67	13250	15	1988	1325	1159	975	853	18.5	18029	15775	40	35	0.02	0.02	Y
HOLIDAY	Y	Y	0.75	0.50	10.75	31973	15	4796	3597	2398	2646	1764	18.5	48943	32629	108	72	0.05	0.04	Y
JUBILEE	Y	Y	0.90	0.48	8.87	31962	15	4794	4315	2317	3174	1704	18.5	58711	31530	129	69	0.06	0.03	Y
VIKING SERENADE	Y	Y	1.00	0.47	9.62	27000	15	4050	4050	1890	2979	1390	18.5	55107	25717	121	57	0.06	0.03	Y
AYA II	Y	Y	1.58	0.83	6.25	16880	15	2532	4009	2110	2949	1552	14.79	43610	22953	96	51	0.05	0.03	Y
BELLONA	Y	Y	0.03	0.75	18.97	11560	15	1734	58	1301	43	957	18.5	786	17696	2	39	0.00	0.02	Y
FRANCONIA	Y	No	1.07	0.72	2.08	12480	15	1872	1997	1342	1469	987	18.5	27170	18255	60	40	0.03	0.02	Y
GREEN LAKE	Y	Y	1.25	0.83	17.50	13119	15	1968	2460	1640	1809	1206	18.5	33470	22313	74	49	0.04	0.02	Y
HUAL CARMENCITA	Y	Y	1.33	0.72	11.95	1300	15	195	260	140	191	103	18.5	3538	1902	8	4	0.00	0.00	Y
OPAL RAY	Y	No	1.17	0.75	97.98	12400	15	1860	2170	1395	1596	1026	18.5	29527	18981	65	42	0.03	0.02	Y
STOLT TENACITY	Y	No	0.25	0.75	52.23	17400	20	3480	870	2610	640	1920	18.5	11838	35514	26	78	0.01	0.04	Y
BT NESTOR	No	Y	0.78	0.38	27.20	16799	15	2520	1974	966	1452	710	18.5	26858	13143	59	29	0.03	0.01	No
SAMUEL GINN	Y	No	0.75	0.75	23.90	18900	15	2835	2126	2126	1564	1564	18.5	28931	28931	64	64	0.03	0.03	Y
ACAPULCO	Y	Y	4.00	0.42	33.50	30991	10	3099	12396	1291	9118	950	18.59	169495	17656	373	39	0.19	0.02	Y
ALLIGATOR BRAVERY	Y	Y	1.33	0.92	41.50	46960	10	4696	6261	4305	4605	3166	18.59	85611	58857	189	130	0.09	0.06	Y
APL SINGAPORE	No	Y	0.73	0.47	75.20	66398	10	6640	4869	3099	3581	2279	18.59	66576	42367	147	93	0.07	0.05	No
AXEL MAERSK	No	Y	0.67	0.45	19.30	45800	10	4580	3053	2061	2246	1516	18.59	41748	28180	92	62	0.05	0.03	No
BRISBANE STAR	Y	No	1.25	1.17	10.15	29000	10	2900	3625	3383	2666	2488	18.59	49564	46260	109	102	0.05	0.05	Y
BROOKLYN BRIDGE	No	Y	0.88	0.48	40.93	37440	10	3744	3307	1810	2432	1331	18.59	45219	24743	100	54	0.05	0.03	No
CALIFORNIA JUPITER	Y	No	1.00	1.08	18.23	29520	10	2952	2952	3198	2171	2352	18.59	40363	43726	89	96	0.04	0.05	Y
CALIFORNIA SATURN	Y	No	1.75	0.83	8.40	29610	10	2961	5182	2468	3811	1815	18.59	70850	33738	156	74	0.08	0.04	Y
CAPE CHARLES	No	Y	0.95	0.77	2.40	32800	10	3280	3116	2515	2292	1850	18.59	42605	34383	94	76	0.05	0.04	No
CHASTINE MAERSK	Y	No	0.83	0.33	50.07	14248	10	1425	1187	475	873	349	18.59	16234	6494	36	14	0.02	0.01	Y
CHETUMAL	Y	Y	0.58	0.17	36.50	38542	10	3854	2248	642	1654	472	18.59	30741	8783	68	19	0.03	0.01	Y
DIRECT EAGLE	Y	No	0.67	0.37	40.23	22799	10	2280	1520	836	1118	615	14.94	16702	9186	37	20	0.02	0.01	Y
DOLE ECUADOR	Y	Y	1.00	0.80	29.20	20650	10	2065	2065	1652	1519	1215	18.59	28235	22588	62	50	0.03	0.02	Y
EMPRESS DRAGON	Y	Y	0.73	0.25	47.77	42100	10	4210	3087	1053	2271	774	18.59	42213	14391	93	32	0.05	0.02	Y
EVER GLOWING	Y	No	1.00	0.48	5.65	23180	10	2318	2318	1120	1705	824	18.59	31694	15319	70	34	0.03	0.02	Y
EVER GRADE	No	Y	0.92	0.42	28.67	21600	10	2160	1980	900	1456	662	18.59	27072	12306	60	27	0.03	0.01	No
EVER RACER	Y	No	0.83	1.00	17.98	42120	10	4212	3510	4212	2582	3098	18.59	47992	57590	106	127	0.05	0.06	Y
EVER UNION	No	Y	1.08	0.50	44.00	59510	10	5951	6447	2976	4742	2188	18.59	88148	40684	194	90	0.10	0.04	No
GEORGE WASHINGTON BRIDGE	Y	Y	0.78	0.45	69.02	28645	10	2865	2244	1289	1650	948	18.59	30680	17625	68	39	0.03	0.02	Y
HANJIN LONDON	Y	No	1.12	0.83	0.28	74494	10	7449	8318	6208	6118	4566	18.59	113738	84879	251	187	0.13	0.09	Y
HANJIN PARIS	No	Y	0.92	0.92	13.00	74494	10	7449	6829	6829	5022	5022	18.59	93367	93367	206	206	0.10	0.10	No
HYUNDAI DYNASTY	Y	Y	0.95	0.95	43.52	32560	10	3256	3093	3093	2275	2275	18.59	42293	42293	93	93	0.05	0.05	Y
HYUNDAI FREEDOM	Y	No	1.67	0.95	2.82	74419	10	7442	12403	7070	9123	5200	18.59	169588	96665	374	213	0.19	0.11	Y
HYUNDAI INDEPENDENCE	No	Y	0.87	2.33	13.00	74520	10	7452	6458	17388	4750	12789	18.59	88305	237745	195	524	0.10	0.26	No

Table B-1

Activity Data and NOx Marine Vessel Inventory for the August 3-7, 1997 Episode

	Maneuvering				Maneuvering															
Ship Name	Entry Manvg (Y/N)	Exit Manvg (Y/N)	Entry Manvg (hrs)	Exit Manvg (hrs)	(Hrs at port-Manc) Hotelling (hrs)	Actual HP Llyods	% MCR @ 5 kts Manvg	Manvg Power (bhp)	Entry Manvg power hp-hr	Exit Manvg power hp-hr	Entry Manvg power (kWh)	Exit Manvg power (kWh)	NOx EMSFAC Manvg (g/kWh)	Entry Manvg NOx (g)	Exit Manvg NOx (g)	Entry Manvg NOx (lbs.)	Exit Manvg NOx (lbs.)	Entry Manvg NOx (tons)	Exit Manvg NOx (tons)	Aux. Entry All Cruise (Y/N)
LUTJENBURG	No	Y	0.67	0.25	6.50	36353	10	3635	2424	909	1783	668	18.59	33137	12426	73	27	0.04	0.01	No
MAGLEBY MAERSK	Y	Y	0.58	0.33	21.67	57677	10	5768	3364	1923	2475	1414	18.59	46003	26287	101	58	0.05	0.03	Y
MARE CASPIUM	Y	Y	0.75	0.73	37.43	27500	10	2750	2063	2017	1517	1483	18.59	28200	27574	62	61	0.03	0.03	Y
MAREN MAERSK	Y	Y	0.73	0.38	13.30	57677	10	5768	4230	2211	3111	1626	18.59	57832	30230	127	67	0.06	0.03	Y
MELBOURNE STAR	No	Y	0.85	0.83	42.08	17100	10	1710	1454	1425	1069	1048	18.59	19874	19484	44	43	0.02	0.02	No
MING PLENTY	Y	Y	1.08	1.00	63.58	23690	10	2369	2566	2369	1888	1742	18.59	35090	32391	77	71	0.04	0.04	Y
MOKIHANA	Y	Y	0.75	0.72	38.62	43200	10	4320	3240	3096	2383	2277	18.59	44300	42331	98	93	0.05	0.05	Y
N O L RUBY	No	Y	0.92	0.90	41.10	38070	10	3807	3490	3426	2567	2520	18.59	47715	46848	105	103	0.05	0.05	No
N O L ZIRCON	No	Y	0.95	0.95	74.72	38070	10	3807	3617	3617	2660	2660	18.59	49450	49450	109	109	0.05	0.05	No
NEPTUNE JADE	Y	Y	1.08	0.62	10.80	31479	10	3148	3410	1941	2508	1428	18.59	46628	26542	103	58	0.05	0.03	Y
NYK SEABREEZE	No	Y	1.10	0.92	19.25	40500	10	4050	4455	3713	3277	2731	18.59	60913	50761	134	112	0.07	0.06	No
OOCL AMERICA	No	Y	0.67	0.70	76.80	66120	10	6612	4408	4628	3242	3404	18.59	60270	63284	133	139	0.07	0.07	No
SEA-LAND CHARGER	No	Y	0.62	0.42	26.00	49589	10	4959	3058	2066	2249	1520	18.59	41812	28251	92	62	0.05	0.03	No
SEA-LAND GUATEMALA	Y	Y	0.55	0.38	15.32	11968	10	1197	658	459	484	337	14.94	7233	5041	16	11	0.01	0.01	Y
SEA-LAND PATRIOT	Y	Y	0.85	2.25	55.82	30150	10	3015	2563	6784	1885	4989	18.59	35040	92754	77	204	0.04	0.10	Y
SOVCOMFLOT SENATOR	Y	Y	0.67	0.42	28.92	29470	10	2947	1965	1228	1445	903	18.59	26863	16789	59	37	0.03	0.02	Y
VLADIVOSTOK SENATOR	Y	Y	0.60	0.50	33.65	29501	10	2950	1770	1475	1302	1085	18.59	24202	20168	53	44	0.03	0.02	Y
YURIY OSTROVSKIY	No	Y	0.67	0.47	1.53	9421	10	942	628	440	462	323	18.59	8588	6011	19	13	0.01	0.01	No
ZIM AMERICA	No	Y	0.82	0.72	17.37	29440	10	2944	2404	2110	1768	1552	18.59	32873	28848	72	64	0.04	0.03	No
ZIM CANADA	Y	No	0.57	0.55	7.17	29440	10	2944	1668	1619	1227	1191	18.59	22810	22139	50	49	0.03	0.02	Y
CHEVRON COLORADO	Y	Y	1.03	0.75	35.30	12500	15	1875	1938	1406	1425	1034	18.5	26363	19134	58	42	0.03	0.02	Y
CHEVRON OREGON	Y	Y	0.75	0.75	0.17	12500	15	1875	1406	1406	1034	1034	18.5	19134	19134	42	42	0.02	0.02	Y
						RFC @ Full (80%) Power (gal/hr)		RFC @ %MCR Manvg (gal/hr)	Entry Manvg FC (gals)	Exit Manvg FC (gals)			Cruise Ems Factors (lb/ 1000gal)			Entry Manvg NOx (lbs.)	Exit Manvg NOx (lbs.)	Entry Manvg PZC NOx (tons)	Exit Manvg NOx (tons)	
ARCO INDEPENDENCE	Y	No	1.05	0.75	23.43	2093.4	15	392.5125	412	294			55.8			23	16	0.01	0.01	Y
ARCO PRUDHOE BAY	No	Y	0.75	0.75	43.83	1238.6	15	232.2375	174	174			55.8			10	10	0.00	0.00	No
ARCO SAG RIVER	Y	No	1.40	0.60	47.60	1128.1	15	211.5188	296	127			55.8			17	7	0.01	0.00	Y
ARCO SPIRIT	No	Y	1.55	0.75	17.25	2093.4	15	392.5125	608	294			55.8			34	16	0.02	0.01	No
BLUE RIDGE	Y	No	1.00	0.75	57.23	793.8	15	148.8375	149	112			55.8			8	6	0.00	0.00	Y
FREDERICKSBURG	Y	Y	1.00	0.75	47.33	1238.6	15	232.2375	232	174			55.8			13	10	0.01	0.00	Y
MARINE CHEMIST	Y	No	0.38	0.75	22.10	1017.6	15	190.8	73	143			55.8			4	8	0.00	0.00	Y
EWA	Y	Y	1.25	1.25	17.75	1604.9	10	200.6125	251	251			55.8			14	14	0.01	0.01	Y
KAUAI	Y	Y	1.00	0.95	57.80	1279.3	10	159.9125	160	152			55.8			9	8	0.00	0.00	Y
SEA-LAND CHALLENGER	Y	No	0.47	0.60	17.35	909.4	10	113.675	53	68			55.8			3	4	0.00	0.00	Y
MATSONIA	Y	No	1.50	1.18	30.98	989.3	10	123.6625	185	146			55.8			10	8	0.01	0.00	Y
																		3.5	2.9	

Table B-1

Activity Data and NOx Marine Vessel Inventory for the August 3-7, 1997 Episode

	Auxiliary Boiler All Cruise					Auxiliary Boiler All Cruise			Auxiliary Boiler-Hotelling & Manvg				Generators						
Ship Name	Aux. Exit All Cruise (Y/N)	Entry All Cruise Time (hrs)	Exit All Cruise Time (hrs)	EMSFAC All Cruise (lb/hr)	Entry All Cruise NOx (lbs.)	Exit All Cruise NOx (lbs.)	Entry All Cruise NOx (tons)	Exit All Cruise NOx (tons)	Aug 3-7th only-Hrs at Port	EMSFAC Hotelling +Manvg (lb/hour)	Hotelling+ Manvg NOx (lbs.)	Hotelling+ Manvg NOx (tons)	Entry Cruise NOx (tons)	Exit Cruise NOx (tons)	Entry PZC NOx (tons)	Exit PZC NOx (tons)	Entry Manvg NOx (tons)	Exit Manvg NOx (tons)	Entry Cruise NOx (tons)
BEL ACE	Y	3.27	3.63	2.7	8.83	9.80	0.004	0.005	4.4	2.7	12	0.006	0.015	0.018	0.003	0.003	0.002	0.003	0.015
FARENCO	No	3.57	3.33	2.7	9.63	8.99	0.005	0.004	103.2	2.7	279	0.139	0.016	0.016	0.004	0.003	0.002	0.015	0.016
FIVI	No	3.15	3.00	2.7	8.50	8.09	0.004	0.004	120.0	2.7	324	0.162	0.013	0.012	0.002	0.001	0.008	0.007	
MODI	Y	3.66	3.35	2.7	9.89	9.04	0.005	0.005	11.5	2.7	31	0.016	0.017	0.016	0.004	0.003	0.002	0.002	0.017
NOSHIRO MARU	Y	3.59	3.42	2.7	9.68	9.24	0.005	0.005	89.8	2.7	243	0.121	0.018	0.018	0.002	0.002	0.005	0.003	
OTRADA	Y	2.91	2.70	2.7	7.87	7.30	0.004	0.004	14.3	2.7	38	0.019	0.016	0.016	0.002	0.002	0.008	0.005	
PERICLES C.G.	Y	3.57	3.25	2.7	9.63	8.79	0.005	0.004	19.6	2.7	53	0.026	0.014	0.014	0.003	0.002	0.006	0.004	
SAGACIOUS NIKE	No	3.57	3.33	2.7	9.63	8.98	0.005	0.004	80.7	2.7	218	0.109	0.016	0.016	0.004	0.003	0.004	0.007	0.016
SINGAPORE ACE	No	4.02	3.77	2.7	10.86	10.18	0.005	0.005	46.4	2.7	125	0.063	0.024	0.024	0.005	0.004	0.004	0.009	0.024
PACPRINCE	Y	3.73	3.41	2.7	10.08	9.22	0.005	0.005	21.6	2.7	58	0.029	0.019	0.018	0.004	0.003	0.003	0.008	0.019
PACPRINCESS	No	3.04	3.36	2.7	8.20	9.08	0.004	0.005	34.3	2.7	93	0.046	0.015	0.018	0.003	0.003	0.008	0.008	0.015
STAR DROTTANGER	Y	3.17	3.35	2.7	8.56	9.04	0.004	0.005	40.5	2.7	109	0.055	0.020	0.022	0.005	0.004	0.011	0.005	0.020
KARINA BONITA	Y	3.28	2.99	2.7	8.86	8.06	0.004	0.004	43.8	2.7	118	0.059	0.013	0.012	0.003	0.002	0.002	0.005	0.013
STAR GRIP	Y	3.08	2.86	2.7	8.32	7.73	0.004	0.004	8.3	2.7	22	0.011	0.024	0.023	0.003	0.003	0.011	0.006	0.024
VAIMAMA	Y	2.99	3.31	2.7	8.07	8.93	0.004	0.004	19.8	2.7	54	0.027	0.025	0.029	0.006	0.005	0.008	0.004	0.025
CHIQUITA FRANCES	No	2.41	2.59	2.7	6.51	6.99	0.003	0.003	20.1	2.7	54	0.027	0.035	0.039	0.010	0.009	0.029	0.009	0.035
MAGIC	Y	2.41	2.59	2.7	6.51	6.99	0.003	0.003	21.2	2.7	57	0.029	0.027	0.030	0.008	0.007	0.013	0.013	0.027
TUNDRA KING	Y	2.57	2.38	2.7	6.95	6.42	0.003	0.003	12.9	2.7	35	0.017	0.023	0.022	0.004	0.003	0.007	0.006	0.023
HOLIDAY	Y	3.53	3.75	2.7	9.53	10.12	0.005	0.005	12.0	2.7	32	0.016	0.098	0.110	0.021	0.017	0.025	0.017	0.098
JUBILEE	Y	3.30	3.49	2.7	8.90	9.41	0.004	0.005	10.2	2.7	28	0.014	0.090	0.101	0.021	0.017	0.030	0.016	0.090
VIKING SERENADE	Y	3.72	3.95	2.7	10.03	10.68	0.005	0.005	11.1	2.7	30	0.015	0.077	0.086	0.016	0.012	0.025	0.012	0.077
AYA II	Y	2.70	2.88	2.7	7.29	7.78	0.004	0.004	8.7	2.7	23	0.012	0.014	0.016	0.004	0.003	0.010	0.005	0.014
BELLONA	Y	3.11	2.88	2.7	8.39	7.78	0.004	0.004	19.8	2.7	53	0.027	0.028	0.027	0.008	0.006	0.000	0.008	0.028
FRANCONIA	No	2.65	2.92	2.7	7.16	7.89	0.004	0.004	3.1	2.7	9	0.004	0.018	0.021	0.005	0.004	0.009	0.006	0.018
GREEN LAKE	Y	3.08	2.85	2.7	8.30	7.69	0.004	0.004	19.6	2.7	53	0.026	0.026	0.025	0.007	0.005	0.013	0.009	0.026
HUAL CARMENCITA	Y	2.77	2.63	2.7	7.48	7.09	0.004	0.004	14.0	2.7	38	0.019	0.024	0.023	0.004	0.003	0.013	0.007	0.024
OPAL RAY	No	2.80	2.66	2.7	7.57	7.18	0.004	0.004	99.1	2.7	268	0.134	0.011	0.011	0.002	0.001	0.005	0.003	0.011
STOLT TENACITY	No	3.54	3.01	2.7	9.56	8.13	0.005	0.004	52.5	2.7	142	0.071	0.028	0.024	0.006	0.005	0.002	0.007	0.028
BT NESTOR	Y	2.86	3.09	2.7	7.71	8.34	0.004	0.004	27.6	2.7	74	0.037	0.020	0.022	0.005	0.004	0.007	0.003	
SAMUEL GINN	No	3.99	3.48	2.7	10.78	9.40	0.005	0.005	24.7	2.7	67	0.033	0.034	0.030	0.007	0.005	0.008	0.008	0.034
ACAPULCO	Y	2.32	2.45	2.7	6.27	6.61	0.003	0.003	37.9	2.7	102	0.051	0.020	0.023	0.007	0.006	0.048	0.005	0.020
ALLIGATOR BRAVERY	Y	2.24	2.11	2.7	6.04	5.69	0.003	0.003	43.8	2.7	118	0.059	0.029	0.029	0.006	0.005	0.021	0.014	0.029
APL SINGAPORE	Y	2.03	1.91	2.7	5.49	5.16	0.003	0.003	75.7	2.7	204	0.102	0.047	0.046	0.011	0.008	0.021	0.013	
AXEL MAERSK	Y	2.48	2.27	2.7	6.70	6.13	0.003	0.003	19.7	2.7	53	0.027	0.031	0.030	0.011	0.008	0.011	0.008	
BRISBANE STAR	No	2.52	2.38	2.7	6.80	6.43	0.003	0.003	11.4	2.7	31	0.015	0.023	0.023	0.004	0.003	0.014	0.013	0.023
BROOKLYN BRIDGE	Y	2.73	2.51	2.7	7.38	6.79	0.004	0.003	41.4	2.7	112	0.056	0.028	0.027	0.009	0.007	0.012	0.007	
CALIFORNIA JUPITER	No	2.37	2.24	2.7	6.41	6.05	0.003	0.003	19.2	2.7	52	0.026	0.023	0.022	0.004	0.003	0.011	0.012	0.023
CALIFORNIA SATURN	No	2.32	2.45	2.7	6.27	6.61	0.003	0.003	10.1	2.7	27	0.014	0.019	0.022	0.007	0.006	0.020	0.009	0.019
CAPE CHARLES	Y	2.32	2.45	2.7	6.27	6.61	0.003	0.003	3.2	2.7	9	0.004	0.021	0.024	0.008	0.006	0.012	0.010	
CHASTINE MAERSK	No	2.56	2.76	2.7	6.92	7.44	0.003	0.004	50.9	2.7	137	0.069	0.028	0.032	0.008	0.007	0.012	0.005	0.028
CHETUMAL	Y	2.25	2.07	2.7	6.06	5.59	0.003	0.003	37.3	2.7	101	0.050	0.028	0.027	0.006	0.004	0.009	0.003	0.028
DIRECT EAGLE	No	2.72	2.52	2.7	7.33	6.79	0.004	0.003	40.9	2.7	110	0.055	0.021	0.020	0.003	0.003	0.006	0.003	0.021
DOLE ECUADOR	Y	2.48	2.57	2.7	6.68	6.93	0.003	0.003	31.0	2.7	84	0.042	0.028	0.032	0.010	0.008	0.015	0.012	0.028
EMPRESS DRAGON	Y	2.55	2.34	2.7	6.89	6.31	0.003	0.003	48.8	2.7	132	0.066	0.028	0.027	0.010	0.007	0.011	0.004	0.028
EVER GLOWING	No	2.49	2.30	2.7	6.73	6.22	0.003	0.003	6.7	2.7	18	0.009	0.020	0.019	0.003	0.003	0.009	0.004	0.020
EVER GRADE	Y	2.52	2.38	2.7	6.80	6.43	0.003	0.003	29.1	2.7	79	0.039	0.017	0.017	0.003	0.002	0.007	0.003	
EVER RACER	No	2.24	2.30	2.7	6.04	6.21	0.003	0.003	18.8	2.7	51	0.025	0.025	0.028	0.010	0.008	0.013	0.015	0.025
EVER UNION	Y	2.33	2.20	2.7	6.30	5.94	0.003	0.003	44.5	2.7	120	0.060	0.039	0.038	0.007	0.006	0.022	0.010	
GEORGE WASHINGTON BRIDGE	Y	2.63	2.41	2.7	7.09	6.51	0.004	0.003	70.2	2.7	190	0.095	0.023	0.022	0.008	0.006	0.009	0.005	0.023
HANJIN LONDON	No	2.36	2.15	2.7	6.36	5.80	0.003	0.003	1.4	2.7	4	0.002	0.044	0.043	0.017	0.013	0.029	0.022	0.044
HANJIN PARIS	Y	2.49	2.28	2.7	6.72	6.14	0.003	0.003	13.9	2.7	38	0.019	0.047	0.046	0.017	0.013	0.024	0.024	
HYUNDAI DYNASTY	Y	2.71	2.49	2.7	7.32	6.73	0.004	0.003	45.4	2.7	123	0.061	0.031	0.030	0.010	0.008	0.014	0.014	0.031
HYUNDAI FREEDOM	No	2.33	2.12	2.7	6.28	5.72	0.003	0.003	4.5	2.7	12	0.006	0.033	0.032	0.013	0.010	0.033	0.019	0.033
HYUNDAI INDEPENDENCE	Y	2.37	2.16	2.7	6.40	5.84	0.003	0.003	15.3	2.7	41	0.021	0.034	0.033	0.013	0.010	0.017	0.047	

Table B-1

Activity Data and NOx Marine Vessel Inventory for the August 3-7, 1997 Episode

	Auxiliary Boiler All Cruise					Auxiliary Boiler All Cruise			Auxiliary Boiler-Hotelling & Manvg				Generators						
Ship Name	Aux. Exit All Cruise (Y/N)	Entry All Cruise Time (hrs)	Exit All Cruise Time (hrs)	EMSFAC All Cruise (1b/hr)	Entry All Cruise NOx (lbs.)	Exit All Cruise NOx (lbs.)	Entry All Cruise NOx (tons)	Exit All Cruise NOx (tons)	Aug 3-7th only-Hrs at Port	EMSFAC Hotelling +Manvg (lb/hour)	Hotelling+ Manvg NOx (lbs.)	Hotelling+ Manvg NOx (tons)	Entry Cruise NOx (tons)	Exit Cruise NOx (tons)	Entry PZC NOx (tons)	Exit PZC NOx (tons)	Entry Manvg NOx (tons)	Exit Manvg NOx (tons)	Entry Cruise NOx (tons)
LUTJENBURG	Y	2.62	2.62	2.7	7.07	7.09	0.004	0.004	6.8	2.7	18	0.009	0.024	0.026	0.008	0.006	0.008	0.003	
MAGLEBY MAERSK	Y	1.97	2.14	2.7	5.33	5.79	0.003	0.003	22.6	2.7	61	0.030	0.063	0.072	0.024	0.022	0.026	0.015	0.063
MARE CASPIUM	Y	2.61	2.39	2.7	7.04	6.46	0.004	0.003	38.9	2.7	105	0.053	0.023	0.022	0.008	0.006	0.009	0.009	0.023
MAREN MAERSK	Y	2.38	2.12	2.7	6.42	5.73	0.003	0.003	14.4	2.7	39	0.019	0.075	0.071	0.029	0.022	0.032	0.017	0.075
MELBOURNE STAR	Y	2.70	2.82	2.7	7.29	7.61	0.004	0.004	42.9	2.7	116	0.058	0.037	0.042	0.011	0.009	0.015	0.015	
MING PLENTY	Y	2.47	2.33	2.7	6.67	6.30	0.003	0.003	65.7	2.7	177	0.089	0.024	0.023	0.004	0.003	0.012	0.011	0.024
MOKIHANA	Y	2.14	2.01	2.7	5.77	5.43	0.003	0.003	40.1	2.7	108	0.054	0.050	0.048	0.011	0.008	0.021	0.020	0.050
N O L RUBY	Y	2.24	2.11	2.7	6.04	5.69	0.003	0.003	42.0	2.7	113	0.057	0.023	0.023	0.005	0.004	0.011	0.011	
N O L ZIRCON	Y	2.24	2.11	2.7	6.04	5.69	0.003	0.003	75.7	2.7	204	0.102	0.023	0.023	0.005	0.004	0.012	0.012	
NEPTUNE JADE	Y	2.63	2.43	2.7	7.10	6.57	0.004	0.003	12.5	2.7	34	0.017	0.025	0.024	0.004	0.003	0.012	0.007	0.025
NYK SEABREEZE	Y	2.49	2.35	2.7	6.71	6.35	0.003	0.003	20.2	2.7	54	0.027	0.036	0.035	0.006	0.005	0.019	0.016	
OOCL AMERICA	Y	3.32	3.08	2.7	8.95	8.32	0.004	0.004	77.5	2.7	209	0.105	0.063	0.061	0.016	0.012	0.016	0.017	
SEA-LAND CHARGER	Y	2.50	2.29	2.7	6.75	6.17	0.003	0.003	26.4	2.7	71	0.036	0.045	0.044	0.017	0.012	0.015	0.010	
SEA-LAND GUATEMALA	Y	2.59	2.79	2.7	7.00	7.54	0.004	0.004	16.3	2.7	44	0.022	0.032	0.036	0.008	0.008	0.009	0.006	0.032
SEA-LAND PATRIOT	Y	3.01	2.78	2.7	8.12	7.51	0.004	0.004	58.9	2.7	159	0.080	0.034	0.033	0.010	0.007	0.012	0.033	0.034
SOVCOMFLOT SENATOR	Y	2.32	2.54	2.7	6.27	6.86	0.003	0.003	30.0	2.7	81	0.041	0.024	0.028	0.007	0.007	0.009	0.006	0.024
VLADIVOSTOK SENATOR	Y	2.42	2.17	2.7	6.55	5.86	0.003	0.003	34.8	2.7	94	0.047	0.024	0.023	0.009	0.007	0.008	0.007	0.024
YURIY OSTROVSKIY	Y	2.95	2.67	2.7	7.96	7.20	0.004	0.004	2.0	2.7	5	0.003	0.026	0.024	0.008	0.006	0.008	0.005	
ZIM AMERICA	Y	2.32	2.54	2.7	6.27	6.86	0.003	0.003	18.1	2.7	49	0.024	0.025	0.029	0.008	0.007	0.011	0.010	
ZIM CANADA	No	2.98	2.69	2.7	8.04	7.27	0.004	0.004	7.7	2.7	21	0.010	0.032	0.031	0.009	0.007	0.008	0.008	0.032
									0.0										
									0.0										
CHEVRON COLORADO	Y	2.95	3.59	2.7	7.97	9.68	0.004	0.005	37.1	2.7	100	0.050	0.060	0.077	0.013	0.012	0.026	0.019	0.060
CHEVRON OREGON	Y	3.18	3.87	2.7	8.58	10.45	0.004	0.005	1.7	2.7	5	0.002	0.065	0.084	0.013	0.012	0.019	0.019	0.065
		Entry All Cruise Time (hrs)	Exit All Cruise Time (hrs)	EMSFAC All Cruise (1b/hr)	Entry All Cruise NOx (lbs.)	Exit All Cruise NOx (lbs.)	Entry All Cruise NOx (tons)	Exit All Cruise NOx (tons)		Hotelling Ems Factors (lb/ 1000gal)	RFC @ 40% power Hotelling (gal/hr)								
ARCO INDEPENDENCE	No								23.4	36.4	1047	0.446							
ARCO PRUDHOE BAY	Y								43.8	36.4	619	0.494							
ARCO SAG RIVER	No								47.6	36.4	564	0.489							
ARCO SPIRIT	Y								17.3	36.4	1047	0.329							
BLUE RIDGE	No								57.2	36.4	397	0.413							
FREDERICKSBURG	Y								47.3	36.4	619	0.534							
MARINE CHEMIST	No								22.1	36.4	509	0.205							
EWA	Y								17.8	36.4	802	0.259							
KAUAI	Y								57.8	36.4	640	0.673							
SEA-LAND CHALLENGER	No								17.3	36.4	455	0.144							
MATSONIA	No								31.0	36.4	495	0.279							
												7.542	2.3	2.4	0.6	0.5	1.0	0.8	1.7

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Table B-1

Activity Data and NOx Marine Vessel Inventory for the August 3-7, 1997 Episode

	Generators					Generators		Main Engines						Auxiliary Boilers			Generators	All
Ship Name	Exit Cruise NOx (tons)	Entry PZC NOx (tons)	Exit PZC NOx (tons)	Entry Manvg NOx (tons)	Exit Manvg NOx (tons)	Hotelling NOx (tons)	Generator NOx (tons)	Entry Cruise NOx (tons)	Exit Cruise NOx (tons)	Entry PZC NOx (tons)	Exit PZC NOx (tons)	Entry Manvg NOx (tons)	Exit Manvg NOx (tons)	Entry All Cruise NOx (tons)	Exit All Cruise NOx (tons)	Hotelling+ Manvg NOx (tons)	Generators For all modes	NOx (tons) for 8/3 thru 8/7
BEL ACE	0.018	0.003	0.003	0.002	0.003	0.014	0.058	0.340	0.390	0.061	0.056	0.011	0.019	0.004	0.005	0.006	0.058	1.0
FARENCO		0.004		0.002		0.423	0.445	0.633		0.099		0.020		0.005		0.139	0.445	1.3
FIVI						0.395	0.395									0.162	0.395	0.6
MODI	0.016	0.004	0.003	0.002	0.002	0.044	0.088	0.441	0.419	0.073	0.055	0.016	0.015	0.005	0.005	0.016	0.088	1.1
NOSHIRO MARU	0.018		0.002		0.003	0.367	0.389		0.389		0.033		0.017		0.005	0.121	0.389	1.0
OTRADA	0.016		0.002		0.005	0.063	0.085		0.361		0.020		0.030		0.004	0.019	0.085	0.5
PERICLES C.G.	0.014		0.002		0.004	0.068	0.088		0.538		0.066		0.038		0.004	0.026	0.088	0.8
SAGACIOUS NIKE		0.004		0.004		0.329	0.353	0.317		0.049		0.021		0.005		0.109	0.353	0.9
SINGAPORE ACE		0.005		0.004		0.242	0.274	0.595		0.120		0.024		0.005		0.063	0.274	1.1
PACPRINCE	0.018	0.004	0.003	0.003	0.008	0.090	0.145	0.327	0.311	0.056	0.042	0.014	0.035	0.005	0.005	0.029	0.145	1.0
PACPRINCESS		0.003		0.008		0.150	0.176	0.266		0.041		0.035		0.004		0.046	0.176	0.6
STAR DROTTANGER	0.022	0.005	0.004	0.011	0.005	0.222	0.289	0.374	0.419	0.068	0.055	0.052	0.026	0.004	0.005	0.055	0.289	1.3
KARINA BONITA	0.012	0.003	0.002	0.002	0.005	0.154	0.192	0.329	0.312	0.042	0.032	0.014	0.031	0.004	0.004	0.059	0.192	1.0
STAR GRIP	0.023	0.003	0.003	0.011	0.006	0.042	0.112	0.307	0.292	0.024	0.018	0.035	0.020	0.004	0.004	0.011	0.112	0.8
VAIMAMA	0.029	0.006	0.005	0.008	0.004	0.138	0.214	0.164	0.188	0.025	0.023	0.016	0.008	0.004	0.004	0.027	0.214	0.7
CHIQUITA FRANCES		0.010		0.029		0.251	0.325	0.251		0.024		0.046		0.003		0.027	0.325	0.7
MAGIC	0.030	0.008	0.007	0.013	0.013	0.203	0.301	0.139	0.155	0.013	0.012	0.014	0.014	0.003	0.003	0.029	0.301	0.7
TUNDRA KING	0.022	0.004	0.003	0.007	0.006	0.089	0.154	0.327	0.311	0.017	0.013	0.020	0.017	0.003	0.003	0.017	0.154	0.9
HOLIDAY	0.110	0.021	0.017	0.025	0.017	0.265	0.554	1.043	1.166	0.240	0.192	0.054	0.036	0.005	0.005	0.016	0.554	3.3
JUBILEE	0.101	0.021	0.017	0.030	0.016	0.219	0.495	0.958	1.071	0.190	0.152	0.065	0.035	0.004	0.005	0.014	0.495	3.0
VIKING SERENADE	0.086	0.016	0.012	0.025	0.012	0.175	0.403	0.937	1.047	0.240	0.192	0.061	0.028	0.005	0.005	0.015	0.403	2.9
AYA II	0.016	0.004	0.003	0.010	0.005	0.030	0.082	0.291	0.334	0.038	0.031	0.048	0.025	0.004	0.004	0.012	0.082	0.9
BELLONA	0.027	0.008	0.006	0.000	0.008	0.156	0.232	0.317	0.309	0.036	0.027	0.001	0.019	0.004	0.004	0.027	0.232	1.0
FRANCONIA		0.005		0.009		0.013	0.045	0.296		0.033		0.030		0.004		0.004	0.045	0.4
GREEN LAKE	0.025	0.007	0.005	0.013	0.009	0.137	0.223	0.355	0.346	0.039	0.029	0.037	0.025	0.004	0.004	0.026	0.223	1.1
HUAL CARMENCITA	0.023	0.004	0.003	0.013	0.007	0.086	0.160	0.035	0.034	0.002	0.002	0.004	0.002	0.004	0.004	0.019	0.160	0.3
OPAL RAY		0.002		0.005		0.322	0.340	0.338		0.021		0.033		0.004		0.134	0.340	0.9
STOLT TENACITY		0.006		0.002		0.365	0.401	0.561		0.068		0.013		0.005		0.071	0.401	1.1
BT NESTOR	0.022		0.004		0.003	0.170	0.200		0.488		0.053		0.014		0.004	0.037	0.200	0.8
SAMUEL GINN		0.007		0.008		0.177	0.225	0.706		0.111		0.032		0.005		0.033	0.225	1.1
ACAPULCO	0.023	0.007	0.006	0.048	0.005	0.292	0.402	0.591	0.678	0.050	0.040	0.187	0.019	0.003	0.003	0.051	0.402	2.0
ALLIGATOR BRAVERY	0.029	0.006	0.005	0.021	0.014	0.478	0.582	0.981	0.957	0.037	0.029	0.094	0.065	0.003	0.003	0.059	0.582	2.8
APL SINGAPORE	0.046		0.008		0.013	1.546	1.613		1.206		0.029		0.047		0.003	0.102	1.613	3.0
AXEL MAERSK	0.030		0.008		0.008	0.238	0.284		0.910		0.045		0.031		0.003	0.027	0.284	1.3
BRISBANE STAR		0.004		0.014		0.080	0.121	0.698		0.034		0.055		0.003		0.015	0.121	0.9
BROOKLYN BRIDGE	0.027		0.007		0.007	0.404	0.444		0.846		0.053		0.027		0.003	0.056	0.444	1.4
CALIFORNIA JUPITER		0.004		0.011		0.150	0.188	0.662		0.029		0.044		0.003		0.026	0.188	1.0
CALIFORNIA SATURN		0.007		0.020		0.069	0.115	0.564		0.048		0.078		0.003		0.014	0.115	0.8
CAPE CHARLES	0.024		0.006		0.010	0.022	0.062		0.717		0.042		0.038		0.003	0.004	0.062	0.9
CHASTINE MAERSK		0.008		0.012		0.515	0.562	0.323		0.033		0.018		0.003		0.069	0.562	1.0
CHETUMAL	0.027	0.006	0.004	0.009	0.003	0.405	0.482	0.809	0.769	0.031	0.024	0.034	0.010	0.003	0.003	0.050	0.482	2.2
DIRECT EAGLE		0.003		0.006		0.265	0.295	0.443		0.028		0.018		0.004		0.055	0.295	0.8
DOLE ECUADOR	0.032	0.010	0.008	0.015	0.012	0.326	0.432	0.429	0.479	0.043	0.034	0.031	0.025	0.003	0.003	0.042	0.432	1.5
EMPRESS DRAGON	0.027	0.010	0.007	0.011	0.004	0.511	0.597	0.891	0.869	0.061	0.046	0.046	0.016	0.003	0.003	0.066	0.597	2.6
EVER GLOWING		0.003		0.009		0.038	0.070	0.551		0.027		0.035		0.003		0.009	0.070	0.7
EVER GRADE	0.017		0.002		0.003	0.165	0.187		0.507		0.020		0.014		0.003	0.039	0.187	0.8
EVER RACER		0.010		0.013		0.201	0.248	0.761		0.058		0.053		0.003		0.025	0.248	1.1
EVER UNION	0.038		0.006		0.010	0.640	0.694		1.276		0.042		0.045		0.003	0.060	0.694	2.1
GEORGE WASHINGTON BRIDGE	0.022	0.008	0.006	0.009	0.005	0.584	0.657	0.630	0.615	0.047	0.035	0.034	0.019	0.004	0.003	0.095	0.657	2.1
HANJIN LONDON		0.017		0.029		0.005	0.096	1.414		0.078		0.125		0.003		0.002	0.096	1.7
HANJIN PARIS	0.046		0.013		0.024	0.246	0.329		1.485		0.073		0.103		0.003	0.019	0.329	2.0
HYUNDAI DYNASTY	0.030	0.010	0.008	0.014	0.014	0.483	0.591	0.747	0.728	0.060	0.045	0.047	0.047	0.004	0.003	0.061	0.591	2.3
HYUNDAI FREEDOM		0.013		0.033		0.041	0.121	1.386		0.074		0.187		0.003		0.006	0.121	1.8
HYUNDAI INDEPENDENCE	0.033		0.010		0.047	0.190	0.280		1.390		0.060		0.262		0.003	0.021	0.280	2.0

Table B-1

Activity Data and NOx Marine Vessel Inventory for the August 3-7, 1997 Episode

	Generators					Generators		Main Engines						Auxiliary Boilers			Generators	All
Ship Name	Exit Cruise NOx (tons)	Entry PZC NOx (tons)	Exit PZC NOx (tons)	Entry Manvg NOx (tons)	Exit Manvg NOx (tons)	Hotelling NOx (tons)	Generator NOx (tons)	Entry Cruise NOx (tons)	Exit Cruise NOx (tons)	Entry PZC NOx (tons)	Exit PZC NOx (tons)	Entry Manvg NOx (tons)	Exit Manvg NOx (tons)	Entry All Cruise NOx (tons)	Exit All Cruise NOx (tons)	Hotelling+ Manvg NOx (tons)	Generators For all modes	NOx (tons) for 8/3 thru 8/7
LUTJENBURG	0.026		0.006		0.003	0.059	0.094		0.867		0.044		0.014		0.004	0.009	0.094	1.0
MAGLEBY MAERSK	0.072	0.024	0.022	0.026	0.015	0.695	0.916	0.927	1.064	0.049	0.045	0.051	0.029	0.003	0.003	0.030	0.916	3.1
MARE CASPIUM	0.022	0.008	0.006	0.009	0.009	0.317	0.392	0.599	0.584	0.043	0.033	0.031	0.030	0.004	0.003	0.053	0.392	1.8
MAREN MAERSK	0.071	0.029	0.022	0.032	0.017	0.426	0.674	1.107	1.051	0.062	0.047	0.064	0.033	0.003	0.003	0.019	0.674	3.1
MELBOURNE STAR	0.042		0.009		0.015	0.554	0.620		0.445		0.040		0.021		0.004	0.058	0.620	1.2
MING PLENTY	0.023	0.004	0.003	0.012	0.011	0.523	0.600	0.557	0.543	0.026	0.020	0.039	0.036	0.003	0.003	0.089	0.600	1.9
MOKIHANA	0.048	0.011	0.008	0.021	0.020	0.794	0.952	0.854	0.833	0.029	0.022	0.049	0.047	0.003	0.003	0.054	0.952	2.8
N O L RUBY	0.023		0.004		0.011	0.372	0.409		0.776		0.023		0.052		0.003	0.057	0.409	1.3
N O L ZIRCON	0.023		0.004		0.012	0.676	0.714		0.776		0.023		0.054		0.003	0.102	0.714	1.7
NEPTUNE JADE	0.024	0.004	0.003	0.012	0.007	0.089	0.165	0.796	0.757	0.043	0.034	0.051	0.029	0.004	0.003	0.017	0.165	1.9
NYK SEABREEZE	0.035		0.005		0.016	0.237	0.293		0.936		0.036		0.056		0.003	0.027	0.293	1.4
OOCL AMERICA	0.061		0.012		0.017	1.326	1.416		1.917		0.194		0.070		0.004	0.105	1.416	3.7
SEA-LAND CHARGER	0.044		0.012		0.010	0.470	0.537		0.994		0.049		0.031		0.003	0.036	0.537	1.7
SEA-LAND GUATEMALA	0.036	0.008	0.008	0.009	0.006	0.175	0.274	0.204	0.228	0.023	0.021	0.008	0.006	0.004	0.004	0.022	0.274	0.8
SEA-LAND PATRIOT	0.033	0.010	0.007	0.012	0.033	0.597	0.727	0.792	0.772	0.082	0.062	0.039	0.102	0.004	0.004	0.080	0.727	2.7
SOVCOMFLOT SENATOR	0.028	0.007	0.007	0.009	0.006	0.285	0.366	0.588	0.675	0.047	0.044	0.030	0.018	0.003	0.003	0.041	0.366	1.8
VLADIVOSTOK SENATOR	0.023	0.009	0.007	0.008	0.007	0.332	0.409	0.582	0.553	0.035	0.026	0.027	0.022	0.003	0.003	0.047	0.409	1.7
YURIY OSTROVSKIY	0.024		0.006		0.005	0.013	0.048		0.229		0.018		0.007		0.004	0.003	0.048	0.3
ZIM AMERICA	0.029		0.007		0.010	0.177	0.223		0.674		0.043		0.032		0.003	0.024	0.223	1.0
ZIM CANADA		0.009		0.008		0.073	0.123	0.763		0.077		0.025		0.004		0.010	0.123	1.0
CHEVRON COLORADO	0.077	0.013	0.012	0.026	0.019	0.638	0.845	0.168	0.214	0.026	0.024	0.029	0.021	0.004	0.005	0.050	0.845	1.4
CHEVRON OREGON	0.084	0.013	0.012	0.019	0.019	0.003	0.215	0.183	0.234	0.033	0.031	0.021	0.021	0.004	0.005	0.002	0.215	0.8
ARCO INDEPENDENCE								0.194		0.030		0.011		0.000		0.446	0.000	0.7
ARCO PRUDHOE BAY									0.083		0.007		0.005		0.000	0.494	0.000	0.6
ARCO SAG RIVER								0.096		0.013		0.008		0.000		0.489	0.000	0.6
ARCO SPIRIT									0.164		0.019		0.008		0.000	0.329	0.000	0.5
BLUE RIDGE								0.055		0.009		0.004		0.000		0.413	0.000	0.5
FREDERICKSBURG								0.095	0.095	0.006	0.004	0.006	0.005	0.000	0.000	0.534	0.000	0.7
MARINE CHEMIST								0.078		0.005		0.002		0.000		0.205	0.000	0.3
EWA								0.093	0.090	0.004	0.003	0.007	0.007	0.000	0.000	0.259	0.000	0.5
KAUAI								0.078	0.129	0.004	0.003	0.004	0.004	0.000	0.000	0.673	0.000	0.9
SEA-LAND CHALLENGER								0.055		0.005		0.001		0.000		0.144	0.000	0.2
MATSONIA								0.088		0.002		0.005		0.000		0.279	0.000	0.4
	1.9	0.4	0.4	0.7	0.6	22.1	27.9	31.5	38.0	3.1	2.6	2.3	2.0	0.2	0.2	7.5	27.9	115.4

Table B-1

Activity Data and NOx Marine Vessel Emissions Inventory for the August 3-7, 1997 Episode (Generator Calculations Only)

Ship Name	Call Sign	Vessel Type	Engine Type	Generators Qty	kW	Qty	kW	Qty	kW	Qty	kW	Cruise kW (80% Use)	PZC kW (80% Use)	Manvg kW (80% Use)	Hotelling kW (55% Use)
BEL ACE	3FMC6	BBU	D	3	500							400	400	400	275
FARENCO	VRUT3	BBU	D	3	500							400	400	400	275
FIVI	P3QK2	BBU	D	3	400							320	320	320	220
MODI	P3JS7	BBU	D	3	500							400	400	400	275
NOSHIRO MARU	JJHU	BBU	D	3	500							400	400	400	275
OTRADA	ELDT6	BBU	D	3	570							456	456	456	313.5
PERICLES C.G.	C4SP	BBU	D	3	440							352	352	352	242
SAGACIOUS NIKE	3FLJ6	BBU	D	3	500							400	400	400	275
SINGAPORE ACE	3FQU4	BBU	D	3	640							512	512	512	352
PACPRINCE	ELED7	BCB	D	3	550							440	440	440	302.5
PACPRINCESS	ELED8	BCB	D	3	550							440	440	440	302.5
STAR DROTTANGER	S6PD	BCB	D	3	700							560	560	560	385
KARINA BONITA	3EHT6	GGC	D	3	440							352	352	352	242
STAR GRIP	LADQ4	GGC	D	3	800							640	640	640	440
VAIMAMA	ELTC7	GGC	D	1	900	2	530					720	720	720	495
CHIQUITA FRANCES	ZCBD9	GRF	D	1	1649	4	650					1319.2	1319.2	1319.2	906.95
MAGIC	PFSJ	GRF	D	1	1275	2	600					1020	1020	1020	701.25
TUNDRA KING	ELNU5	GRF	D	4	928							742.4	742.4	742.4	510.4
HOLIDAY	3FPN5	MPR	D	5	3000							2400	2400	2400	1650
JUBILEE	3FPM5	MPR	D	5	3000							2400	2400	2400	1650
VIKING SERENADE	ELTG6	MPR	D	3	2210	1	2140					1768	1768	1768	1215.5
AYA II	D5HD	MVE	D	3	580							464	464	464	319
BELLONA	3FEA4	MVE	D	3	1000							800	800	800	550
FRANCONIA	ELKV5	MVE	D	2	760							608	608	608	418
GREEN LAKE	KGTI	MVE	D	3	950	1	170					760	760	760	522.5
HUAL CARMENCITA	LAFH4	MVE	D	3	880							704	704	704	484
OPAL RAY	9HKZ4	MVE	D	3	400							320	320	320	220
STOLT TENACITY	D5CP	TCH	D	3	850							680	680	680	467.5
BT NESTOR	VRIY	TTA	D	3	760							608	608	608	418
SAMUEL GINN	C6OB	TTA	D	3	900							720	720	720	495
ACAPULCO	DLAZ	UCC	D	3	1060							848	848	848	583
ALLIGATOR BRAVERY	3FXX4	UCC	D	3	1400	1	1200					1120	1120	1120	770
APL SINGAPORE	V7AL8	UCC	D	1	2500	3	2100					2000	2000	2000	1375
AXEL MAERSK	OXSF2	UCC	D	1	1500	1	1100	3	1000			1200	1200	1200	825
BRISBANE STAR	C6LY4	UCC	D	6	960							768	768	768	528
BROOKLYN BRIDGE	3EZJ9	UCC	D	3	1200	1	1200					960	960	960	660
CALIFORNIA JUPITER	ELKU8	UCC	D	4	1000							800	800	800	550
CALIFORNIA SATURN	ELKU9	UCC	D	4	1000							800	800	800	550
CAPE CHARLES	3EFX5	UCC	D	4	1100							880	880	880	605
CHASTINE MAERSK	OWNJ2	UCC	D	3	1250							1000	1000	1000	687.5
CHETUMAL	SXNO	UCC	D	4	1350							1080	1080	1080	742.5
DIRECT EAGLE	C6BJ9	UCC	D	3	800	1	100					640	640	640	440
DOLE ECUADOR	ELGH3	UCC	D	2	1360	3	1200	1	900			1088	1088	1088	748
EMPRESS DRAGON	3FOZ3	UCC	D	3	1300							1040	1040	1040	715
EVER GLOWING	BKJZ	UCC	D	3	820							656	656	656	451
EVER GRADE	3FOW2	UCC	D	3	700							560	560	560	385
EVER RACER	3FJL4	UCC	D	4	1360							1088	1088	1088	748
EVER UNION	3FFG7	UCC	D	4	1770							1416	1416	1416	973.5
GEORGE WASHINGTON BRIDGE	JKCF	UCC	D	3	1030	1	920					824	824	824	566.5
HANJIN LONDON	DSEI7	UCC	D	2	2300	2	1500					1840	1840	1840	1265
HANJIN PARIS	3FMK7	UCC	D	2	2300	2	1500					1840	1840	1840	1265
HYUNDAI DYNASTY	P3BA7	UCC	D	3	1350							1080	1080	1080	742.5
HYUNDAI FREEDOM	3FFS6	UCC	D	4	1775							1420	1420	1420	976.25
HYUNDAI INDEPENDENCE	3FDY6	UCC	D	4	1775							1420	1420	1420	976.25

Generator Calculations for Steamships are not applicable*

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Activity Data and NOx Marine Vessel Emissions Inventory for the August 3-7, 1997 Episode
(Generator Calculations Only)

Ship Name	Call Sign	Vessel Type	Engine Type	Generators Qty	kW	Qty	kW	Qty	kW	Qty	kW	Cruise kW (80% Use)	PZC kW (80% Use)	Manvg kW (80% Use)	Hotelling kW (55% Use)
LUTJENBURG	DGLU	UCC	D	3	1100							880	880	880	605
MAGLEBY MAERSK	OUSH2	UCC	D	1	3900	1	3000	3	1600			3120	3120	3120	2145
MARE CASPIUM	V2AN5	UCC	D	3	1030	1	920					824	824	824	566.5
MAREN MAERSK	OWZU2	UCC	D	1	3900	3	1600	1	1000			3120	3120	3120	2145
MELBOURNE STAR	C6JY6	UCC	D	2	1600	2	1200					1280	1280	1280	880
MING PLENTY	BLJK	UCC	D	2	1000	2	480					800	800	800	550
MOKIHANA	WNRD	UCC	D	3	2500	2	1640					2000	2000	2000	1375
N O L RUBY	9VOP	UCC	D	3	1100	1	1000					880	880	880	605
N O L ZIRCON	9VOS	UCC	D	3	1100	1	1000					880	880	880	605
NEPTUNE JADE	9VNQ	UCC	D	3	1000	1	600					800	800	800	550
NYK SEABREEZE	ELNJ3	UCC	D	3	1500	1	1200					1200	1200	1200	825
OOCL AMERICA	ELSM7	UCC	D	1	2100							1680	1680	1680	1155
SEA-LAND CHARGER	V7AY2	UCC	D	3	2200							1760	1760	1760	1210
SEA-LAND GUATEMALA	OUJV2	UCC	D	1	1390	3	570					1112	1112	1112	764.5
SEA-LAND PATRIOT	KHRF	UCC	D	2	1300	1	900	1	650	1	240	1040	1040	1040	715
SOVCOMFLOT SENATOR	ELPX5	UCC	D	1	1200	3	910.4	1	144			960	960	960	660
VLADIVOSTOK SENATOR	ELPL2	UCC	D	1	1200	3	910.4	1	144			960	960	960	660
YURIY OSTROVSKIY	UAGJ	UCC	D	1	1000							800	800	800	550
ZIM AMERICA	4XGR	UCC	D	2	1240	1	1200					992	992	992	682
ZIM CANADA	4XGS	UCC	D	2	1240	1	1200					992	992	992	682
CHEVRON COLORADO	KLHZ	TTA	GT	1	2200	1	400					1760	1760	1760	1210
CHEVRON OREGON	WNHL	TTA	GT	1	2200	1	400					1760	1760	1760	1210
ARCO INDEPENDENCE*	KLHV	TTA	ST*												
ARCO PRUDHOE BAY*	KPFD	TTA	ST*												
ARCO SAG RIVER*	WLDF	TTA	ST*												
ARCO SPIRIT*	KHLD	TTA	ST*												
BLUE RIDGE*	KNID	TTA	ST*												
FREDERICKSBURG*	KNIN	TTA	ST*												
MARINE CHEMIST*	KMCB	TTA	ST*												
EWA*	WEZM	UCC	ST*												
KAUAI*	WSRH	UCC	ST*												
SEA-LAND CHALLENGER*	WZJC	UCC	ST*												
MATSONIA*	KHRC	URC	ST*												

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Table B-1

Activity Data and NOx Marine Vessel Emissions Inventory for the August 3-7, 1997 Episode
(Generator Calculations Only)

	Cruise									Precautionary Zone Cruise (PZC)								
Ship Name	Entry Cruise Time (hours)	Exit Cruise Time (hours)	Entry Cruise kWh	Exit Cruise kWh	Medium Speed engines EMSFAC Cruise (g/kWh)	Entry Cruise NOx (g)	Exit Cruise NOx (g)	Entry Cruise NOx (tons)	Exit Cruise NOx (tons)	Entry PZC Time (hours)	Exit PZC Time (hours)	Entry PZC kWh	Exit PZC kWh	Medium Speed engines EMSFAC PZC (g/kWh)	Entry PZC NOx (g)	Exit PZC NOx (g)	Entry PZC NOx (tons)	Exit PZC NOx (tons)
BEL ACE	2.73	3.13	1091	1252	12.81	13982	16038	0.015	0.018	0.54	0.50	217	200	12.81	2776	2562	0.003	0.003
FARENCO	2.90	2.83	1161	1132	12.81	14867	14495	0.016	0.016	0.67	0.50	267	200	12.81	3416	2562	0.004	0.003
FIVI	2.77	2.70	888	866	12.81	11372	11088	0.013	0.012	0.38	0.29	120	93	12.81	1537	1196	0.002	0.001
MODI	3.00	2.85	1199	1139	12.81	15353	14585	0.017	0.016	0.67	0.50	267	200	12.81	3416	2562	0.004	0.003
NOSHIRO MARU	3.21	3.13	1284	1252	12.81	16449	16038	0.018	0.018	0.38	0.29	150	117	12.81	1922	1495	0.002	0.002
OTRADA	2.54	2.41	1158	1100	12.81	14832	14091	0.016	0.016	0.38	0.29	171	133	12.81	2191	1704	0.002	0.002
PERICLES C.G.	2.90	2.75	1021	970	12.81	13075	12421	0.014	0.014	0.67	0.50	235	176	12.81	3006	2255	0.003	0.002
SAGACIOUS NIKE	2.90	2.83	1159	1130	12.81	14852	14481	0.016	0.016	0.67	0.50	267	200	12.81	3416	2562	0.004	0.003
SINGAPORE ACE	3.35	3.27	1717	1674	12.81	21998	21448	0.024	0.024	0.67	0.50	341	256	12.81	4372	3279	0.005	0.004
PACPRINCE	3.07	2.91	1350	1282	12.81	17290	16425	0.019	0.018	0.67	0.50	293	220	12.81	3758	2818	0.004	0.003
PACPRINCESS	2.50	2.86	1099	1260	12.81	14073	16143	0.015	0.018	0.54	0.50	238	220	12.81	3053	2818	0.003	0.003
STAR DROTTANGER	2.55	2.85	1426	1594	12.81	18270	20419	0.020	0.022	0.63	0.50	350	280	12.81	4484	3587	0.005	0.004
KARINA BONITA	2.62	2.49	921	875	12.81	11798	11208	0.013	0.012	0.67	0.50	235	176	12.81	3006	2255	0.003	0.002
STAR GRIP	2.70	2.57	1731	1645	12.81	22177	21068	0.024	0.023	0.38	0.29	240	187	12.81	3074	2391	0.003	0.003
VAIMAMA	2.45	2.81	1761	2020	12.81	22560	25878	0.025	0.029	0.54	0.50	390	360	12.81	4996	4612	0.006	0.005
CHIQUITA FRANCES	1.87	2.09	2464	2754	12.81	31569	35284	0.035	0.039	0.54	0.50	715	660	12.81	9154	8449	0.010	0.009
MAGIC	1.87	2.09	1905	2130	12.81	24409	27281	0.027	0.030	0.54	0.50	553	510	12.81	7078	6533	0.008	0.007
TUNDRA KING	2.20	2.09	1632	1550	12.81	20901	19856	0.023	0.022	0.38	0.29	278	217	12.81	3566	2774	0.004	0.003
HOLIDAY	2.91	3.25	6974	7795	12.81	89342	99852	0.098	0.110	0.63	0.50	1500	1200	12.81	19215	15372	0.021	0.017
JUBILEE	2.67	2.99	6410	7164	12.81	82113	91773	0.090	0.101	0.63	0.50	1500	1200	12.81	19215	15372	0.021	0.017
VIKING SERENADE	3.09	3.45	5465	6108	12.81	70003	78239	0.077	0.086	0.63	0.50	1105	884	12.81	14155	11324	0.016	0.012
AYA II	2.08	2.38	963	1105	12.81	12338	14152	0.014	0.016	0.63	0.50	290	232	12.81	3715	2972	0.004	0.003
BELLONA	2.44	2.38	1954	1905	12.81	25026	24400	0.028	0.027	0.67	0.50	533	400	12.81	6832	5124	0.008	0.006
FRANCONIA	2.11	2.42	1283	1472	12.81	16441	18858	0.018	0.021	0.54	0.50	329	304	12.81	4219	3894	0.005	0.004
GREEN LAKE	2.41	2.35	1830	1785	12.81	23449	22862	0.026	0.025	0.67	0.50	507	380	12.81	6490	4868	0.007	0.005
HUAL CARMENCITA	2.40	2.34	1687	1645	12.81	21607	21067	0.024	0.023	0.38	0.29	264	205	12.81	3382	2630	0.004	0.003
OPAL RAY	2.43	2.37	777	758	12.81	9955	9706	0.011	0.011	0.38	0.29	120	93	12.81	1537	1196	0.002	0.001
STOLT TENACITY	2.88	2.51	1955	1708	12.81	25044	21878	0.028	0.024	0.67	0.50	453	340	12.81	5807	4355	0.006	0.005
BT NESTOR	2.32	2.59	1408	1573	12.81	18033	20154	0.020	0.022	0.54	0.50	329	304	12.81	4219	3894	0.005	0.004
SAMUEL GINN	3.33	2.98	2395	2148	12.81	30685	27511	0.034	0.030	0.67	0.50	480	360	12.81	6149	4612	0.007	0.005
ACAPULCO	1.70	1.95	1440	1652	12.81	18448	21161	0.020	0.023	0.63	0.50	530	424	12.81	6789	5431	0.007	0.006
ALLIGATOR BRAVERY	1.86	1.82	2085	2033	12.81	26714	26046	0.029	0.029	0.38	0.29	420	327	12.81	5380	4185	0.006	0.005
APL SINGAPORE	1.66	1.62	3320	3237	12.81	42523	41460	0.047	0.046	0.38	0.29	750	583	12.81	9608	7473	0.011	0.008
AXEL MAERSK	1.82	1.77	2180	2125	12.81	27921	27223	0.031	0.030	0.67	0.50	800	600	12.81	10248	7686	0.011	0.008
BRISBANE STAR	2.14	2.09	1647	1606	12.81	21095	20567	0.023	0.023	0.38	0.29	288	224	12.81	3689	2869	0.004	0.003
BROOKLYN BRIDGE	2.07	2.01	1983	1933	12.81	25398	24763	0.028	0.027	0.67	0.50	640	480	12.81	8198	6149	0.009	0.007
CALIFORNIA JUPITER	2.00	1.95	1598	1558	12.81	20476	19964	0.023	0.022	0.38	0.29	300	233	12.81	3843	2989	0.004	0.003
CALIFORNIA SATURN	1.70	1.95	1359	1558	12.81	17404	19964	0.019	0.022	0.63	0.50	500	400	12.81	6405	5124	0.007	0.006
CAPE CHARLES	1.70	1.95	1495	1714	12.81	19145	21960	0.021	0.024	0.63	0.50	550	440	12.81	7046	5636	0.008	0.006
CHASTINE MAERSK	2.02	2.26	2020	2257	12.81	25871	28915	0.028	0.032	0.54	0.50	542	500	12.81	6939	6405	0.008	0.007
CHETUMAL	1.87	1.78	2020	1919	12.81	25878	24584	0.028	0.027	0.38	0.29	405	315	12.81	5188	4035	0.006	0.004
DIRECT EAGLE	2.34	2.22	1498	1423	12.81	19194	18235	0.021	0.020	0.38	0.29	240	187	12.81	3074	2391	0.003	0.003
DOLE ECUADOR	1.85	2.07	2013	2250	12.81	25789	28823	0.028	0.032	0.63	0.50	680	544	12.81	8711	6969	0.010	0.008
EMPRESS DRAGON	1.89	1.84	1961	1912	12.81	25122	24494	0.028	0.027	0.67	0.50	693	520	12.81	8882	6661	0.010	0.007
EVER GLOWING	2.12	2.01	1390	1320	12.81	17801	16911	0.020	0.019	0.38	0.29	246	191	12.81	3151	2451	0.003	0.003
EVER GRADE	2.14	2.09	1201	1171	12.81	15382	14997	0.017	0.017	0.38	0.29	210	163	12.81	2690	2092	0.003	0.002
EVER RACER	1.61	1.80	1752	1958	12.81	22445	25086	0.025	0.028	0.63	0.50	680	544	12.81	8711	6969	0.010	0.008
EVER UNION	1.96	1.91	2774	2705	12.81	35536	34648	0.039	0.038	0.38	0.29	531	413	12.81	6802	5291	0.007	0.006
GEORGE WASHINGTON BRIDGE	1.96	1.91	1616	1575	12.81	20697	20180	0.023	0.022	0.67	0.50	549	412	12.81	7037	5278	0.008	0.006
HANJIN LONDON	1.69	1.65	3111	3033	12.81	39849	38852	0.044	0.043	0.67	0.50	1227	920	12.81	15714	11785	0.017	0.013
HANJIN PARIS	1.82	1.78	3351	3267	12.81	42924	41850	0.047	0.046	0.67	0.50	1227	920	12.81	15714	11785	0.017	0.013
HYUNDAI DYNASTY	2.04	1.99	2208	2153	12.81	28285	27578	0.031	0.030	0.67	0.50	720	540	12.81	9223	6917	0.010	0.008
HYUNDAI FREEDOM	1.66	1.62	2357	2298	12.81	30194	29439	0.033	0.032	0.67	0.50	947	710	12.81	12127	9095	0.013	0.010
HYUNDAI INDEPENDENCE	1.71	1.66	2421	2361	12.81	31015	30239	0.034	0.033	0.67	0.50	947	710	12.81	12127	9095	0.013	0.010

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Activity Data and NOx Marine Vessel Emissions Inventory for the August 3-7, 1997 Episode
(Generator Calculations Only)

	Cruise									Precautionary Zone Cruise (PZC)								
Ship Name	Entry Cruise Time (hours)	Exit Cruise Time (hours)	Entry Cruise kWh	Exit Cruise kWh	Medium Speed engines EMSFAC Cruise (g/kWh)	Entry Cruise NOx (g)	Exit Cruise NOx (g)	Entry Cruise NOx (tons)	Exit Cruise NOx (tons)	Entry PZC Time (hours)	Exit PZC Time (hours)	Entry PZC kWh	Exit PZC kWh	Medium Speed engines EMSFAC PZC (g/kWh)	Entry PZC NOx (g)	Exit PZC NOx (g)	Entry PZC NOx (tons)	Exit PZC NOx (tons)
LUTJENBURG	1.95	2.12	1719	1870	12.81	22023	23950	0.024	0.026	0.67	0.50	587	440	12.81	7515	5636	0.008	0.006
MAGLEBY MAERSK	1.43	1.64	4470	5127	12.81	57258	65679	0.063	0.072	0.54	0.50	1690	1560	12.81	21649	19984	0.024	0.022
MARE CASPIUM	1.94	1.89	1600	1560	12.81	20496	19984	0.023	0.022	0.67	0.50	549	412	12.81	7037	5278	0.008	0.006
MAREN MAERSK	1.71	1.62	5333	5067	12.81	68320	64904	0.075	0.071	0.67	0.50	2080	1560	12.81	26645	19984	0.029	0.022
MELBOURNE STAR	2.08	2.32	2657	2969	12.81	34035	38039	0.037	0.042	0.63	0.50	800	640	12.81	10248	8198	0.011	0.009
MING PLENTY	2.09	2.04	1675	1634	12.81	21462	20925	0.024	0.023	0.38	0.29	300	233	12.81	3843	2989	0.004	0.003
MOKIHANA	1.76	1.72	3524	3436	12.81	45145	44017	0.050	0.048	0.38	0.29	750	583	12.81	9608	7473	0.011	0.008
N O L RUBY	1.86	1.82	1639	1598	12.81	20996	20471	0.023	0.023	0.38	0.29	330	257	12.81	4227	3288	0.005	0.004
N O L ZIRCON	1.86	1.82	1639	1598	12.81	20996	20471	0.023	0.023	0.38	0.29	330	257	12.81	4227	3288	0.005	0.004
NEPTUNE JADE	2.25	2.14	1803	1713	12.81	23101	21946	0.025	0.024	0.38	0.29	300	233	12.81	3843	2989	0.004	0.003
NYK SEABREEZE	2.11	2.06	2534	2471	12.81	32460	31649	0.036	0.035	0.38	0.29	450	350	12.81	5765	4484	0.006	0.005
OOCL AMERICA	2.65	2.58	4450	4339	12.81	57009	55584	0.063	0.061	0.67	0.50	1120	840	12.81	14347	10760	0.016	0.012
SEA-LAND CHARGER	1.83	1.79	3223	3143	12.81	41292	40260	0.045	0.044	0.67	0.50	1173	880	12.81	15030	11273	0.017	0.012
SEA-LAND GUATEMALA	2.05	2.29	2281	2549	12.81	29217	32654	0.032	0.036	0.54	0.50	602	556	12.81	7716	7122	0.008	0.008
SEA-LAND PATRIOT	2.34	2.28	2433	2372	12.81	31164	30384	0.034	0.033	0.67	0.50	693	520	12.81	8882	6661	0.010	0.007
SOVCOMFLOT SENATOR	1.78	2.04	1708	1959	12.81	21880	25097	0.024	0.028	0.54	0.50	520	480	12.81	6661	6149	0.007	0.007
VLADIVOSTOK SENATOR	1.76	1.67	1688	1604	12.81	21622	20541	0.024	0.023	0.67	0.50	640	480	12.81	8198	6149	0.009	0.007
YURIY OSTROVSKIY	2.28	2.17	1825	1734	12.81	23377	22208	0.026	0.024	0.67	0.50	533	400	12.81	6832	5124	0.008	0.006
ZIM AMERICA	1.78	2.04	1765	2024	12.81	22609	25934	0.025	0.029	0.54	0.50	537	496	12.81	6883	6354	0.008	0.007
ZIM CANADA	2.31	2.19	2291	2176	12.81	29348	27880	0.032	0.031	0.67	0.50	661	496	12.81	8472	6354	0.009	0.007
CHEVRON COLORADO	2.41	3.09	4244	5430	12.81	54365	69556	0.060	0.077	0.54	0.50	953	880	12.81	12212	11273	0.013	0.012
CHEVRON OREGON	2.63	3.37	4637	5933	12.81	59399	75996	0.065	0.084	0.54	0.50	953	880	12.81	12212	11273	0.013	0.012
ARCO INDEPENDENCE*																		
ARCO PRUDHOE BAY*																		
ARCO SAG RIVER*																		
ARCO SPIRIT*																		
BLUE RIDGE*																		
FREDERICKSBURG*																		
MARINE CHEMIST*																		
EWA*																		
KAUAI*																		
SEA-LAND CHALLENGER*																		
MATSONIA*																		

Generator Calculations for Steamships are not applicable*

Table B-1

Activity Data and NOx Marine Vessel Emissions Inventory for the August 3-7, 1997 Episode (Generator Calculations Only)

	Maneuvering									Hotelling			
Ship Name	Entry Manvg (hrs)	Exit Manvg (hrs)	Entry Manvg kWh	Exit Manvg kWh	Medium Speed engines EMSFAC Manvg (g/kWh)	Entry Manvg NOx (g)	Exit Manvg NOx (g)	Entry Manvg NOx (tons)	Exit Manvg NOx (tons)	Hotelling (hrs)	EMSFAC Hotelling for Medium Speed engines (g/kWh)	Hotelling NOx (g)	Hotelling NOx (tons)
BEL ACE	0.33	0.58	132	232	12.81	1691	2972	0.002	0.003	3.51	13.57	13088	0.01
FARENCO	0.35	2.58	140	1032	12.81	1793	13220	0.002	0.015	102.88	13.57	384006	0.42
FIVI	1.67	1.50	533	480	12.81	6832	6149	0.008	0.007	119.98	13.57	358264	0.39
MODI	0.42	0.38	167	153	12.81	2135	1964	0.002	0.002	10.70	13.57	39937	0.04
NOSHIRO MARU	0.92	0.50	367	200	12.81	4697	2562	0.005	0.003	89.33	13.57	333431	0.37
OTRADA	1.17	0.75	532	342	12.81	6815	4381	0.008	0.005	13.50	13.57	57442	0.06
PERICLES C.G.	1.25	0.73	440	258	12.81	5636	3307	0.006	0.004	18.85	13.57	61914	0.07
SAGACIOUS NIKE	0.72	1.25	287	500	12.81	3672	6405	0.004	0.007	80.02	13.57	298657	0.33
SINGAPORE ACE	0.50	1.25	256	640	12.81	3279	8198	0.004	0.009	45.90	13.57	219288	0.24
PACPRINCE	0.50	1.25	220	550	12.81	2818	7046	0.003	0.008	19.83	13.57	81429	0.09
PACPRINCESS	1.25	1.25	550	550	12.81	7046	7046	0.008	0.008	33.07	13.57	135761	0.15
STAR DROTTANGER	1.33	0.67	747	373	12.81	9565	4782	0.011	0.005	38.50	13.57	201178	0.22
KARINA BONITA	0.42	0.93	147	329	12.81	1879	4209	0.002	0.005	42.48	13.57	139538	0.15
STAR GRIP	1.17	0.67	747	427	12.81	9565	5466	0.011	0.006	6.42	13.57	38320	0.04
VAIMAMA	0.83	0.42	600	300	12.81	7686	3843	0.008	0.004	18.58	13.57	124850	0.14
CHIQUITA FRANCES	1.58	0.50	2089	660	12.81	26757	8449	0.029	0.009	18.48	13.57	227522	0.25
MAGIC	0.88	0.90	901	918	12.81	11542	11760	0.013	0.013	19.38	13.57	184485	0.20
TUNDRA KING	0.67	0.58	495	433	12.81	6340	5548	0.007	0.006	11.67	13.57	80820	0.09
HOLIDAY	0.75	0.50	1800	1200	12.81	23058	15372	0.025	0.017	10.75	13.57	240742	0.27
JUBILEE	0.90	0.48	2160	1160	12.81	27670	14860	0.030	0.016	8.87	13.57	198566	0.22
VIKING SERENADE	1.00	0.47	1768	825	12.81	22648	10569	0.025	0.012	9.62	13.57	158650	0.17
AYA II	1.58	0.83	735	387	12.81	9411	4953	0.010	0.005	6.25	13.57	27060	0.03
BELLONA	0.03	0.75	27	600	12.81	342	7686	0.000	0.008	18.97	13.57	141584	0.16
FRANCONIA	1.07	0.72	649	436	12.81	8308	5582	0.009	0.006	2.08	13.57	11819	0.01
GREEN LAKE	1.25	0.83	950	633	12.81	12170	8113	0.013	0.009	17.50	13.57	124104	0.14
HUAL CARMENCITA	1.33	0.72	939	505	12.81	12024	6463	0.013	0.007	11.95	13.57	78501	0.09
OPAL RAY	1.17	0.75	373	240	12.81	4782	3074	0.005	0.003	97.98	13.57	292573	0.32
STOLT TENACITY	0.25	0.75	170	510	12.81	2178	6533	0.002	0.007	52.23	13.57	331428	0.37
BT NESTOR	0.78	0.38	476	233	12.81	6101	2986	0.007	0.003	27.20	13.57	154314	0.17
SAMUEL GINN	0.75	0.75	540	540	12.81	6917	6917	0.008	0.008	23.90	13.57	160569	0.18
ACAPULCO	4.00	0.42	3392	353	12.81	43452	4526	0.048	0.005	33.50	13.57	265078	0.29
ALLIGATOR BRAVERY	1.33	0.92	1493	1027	12.81	19130	13152	0.021	0.014	41.50	13.57	433709	0.48
APL SINGAPORE	0.73	0.47	1467	933	12.81	18788	11956	0.021	0.013	75.20	13.57	1403397	1.55
AXEL MAERSK	0.67	0.45	800	540	12.81	10248	6917	0.011	0.008	19.30	13.57	216108	0.24
BRISBANE STAR	1.25	1.17	960	896	12.81	12298	11478	0.014	0.013	10.15	13.57	72738	0.08
BROOKLYN BRIDGE	0.88	0.48	848	464	12.81	10863	5944	0.012	0.007	40.93	13.57	366675	0.40
CALIFORNIA JUPITER	1.00	1.08	800	867	12.81	10248	11102	0.011	0.012	18.23	13.57	136110	0.15
CALIFORNIA SATURN	1.75	0.83	1400	667	12.81	17934	8540	0.020	0.009	8.40	13.57	62705	0.07
CAPE CHARLES	0.95	0.77	836	675	12.81	10709	8642	0.012	0.010	2.40	13.57	19707	0.02
CHASTINE MAERSK	0.83	0.33	833	333	12.81	10675	4270	0.012	0.005	50.07	13.57	467177	0.51
CHETUMAL	0.58	0.17	630	180	12.81	8070	2306	0.009	0.003	36.50	13.57	367832	0.41
DIRECT EAGLE	0.67	0.37	427	235	12.81	5466	3006	0.006	0.003	40.23	13.57	240269	0.26
DOLE ECUADOR	1.00	0.80	1088	870	12.81	13937	11150	0.015	0.012	29.20	13.57	296445	0.33
EMPRESS DRAGON	0.73	0.25	763	260	12.81	9770	3331	0.011	0.004	47.77	13.57	463544	0.51
EVER GLOWING	1.00	0.48	656	317	12.81	8403	4062	0.009	0.004	5.65	13.57	34585	0.04
EVER GRADE	0.92	0.42	513	233	12.81	6576	2989	0.007	0.003	28.67	13.57	149795	0.16
EVER RACER	0.83	1.00	907	1088	12.81	11614	13937	0.013	0.015	17.98	13.57	182571	0.20
EVER UNION	1.08	0.50	1534	708	12.81	19651	9069	0.022	0.010	44.00	13.57	581364	0.64
GEORGE WASHINGTON BRIDGE	0.78	0.45	645	371	12.81	8268	4750	0.009	0.005	69.02	13.57	530657	0.58
HANJIN LONDON	1.12	0.83	2055	1533	12.81	26320	19642	0.029	0.022	0.28	13.57	4865	0.01
HANJIN PARIS	0.92	0.92	1687	1687	12.81	21606	21606	0.024	0.024	13.00	13.57	223200	0.25
HYUNDAI DYNASTY	0.95	0.95	1026	1026	12.81	13143	13143	0.014	0.014	43.52	13.57	438543	0.48
HYUNDAI FREEDOM	1.67	0.95	2367	1349	12.81	30317	17281	0.033	0.019	2.82	13.57	37321	0.04
HYUNDAI INDEPENDENCE	0.87	2.33	1231	3313	12.81	15765	42444	0.017	0.047	13.00	13.57	172252	0.19

Generator Calculations for Steamships are not applicable*

Table B-1

Activity Data and NOx Marine Vessel Emissions Inventory for the August 3-7, 1997 Episode
(Generator Calculations Only)

	Maneuvering									Hotelling			
Ship Name	Entry Manvg (hrs)	Exit Manvg (hrs)	Entry Manvg kWh	Exit Manvg kWh	Medium Speed engines EMSFAC Manvg (g/kWh)	Entry Manvg NOx (g)	Exit Manvg NOx (g)	Entry Manvg NOx (tons)	Exit Manvg NOx (tons)	Hotelling (hrs)	EMSFAC Hotelling for Medium Speed engines (g/kWh)	Hotelling NOx (g)	Hotelling NOx (tons)
LUTJENBURG	0.67	0.25	587	220	12.81	7515	2818	0.008	0.003	6.50	13.57	53374	0.06
MAGLEBY MAERSK	0.58	0.33	1820	1040	12.81	23314	13322	0.026	0.015	21.67	13.57	630782	0.69
MARE CASPIUM	0.75	0.73	618	604	12.81	7917	7741	0.009	0.009	37.43	13.57	287818	0.32
MAREN MAERSK	0.73	0.38	2288	1196	12.81	29309	15321	0.032	0.017	13.30	13.57	387203	0.43
MELBOURNE STAR	0.85	0.83	1088	1067	12.81	13937	13664	0.015	0.015	42.08	13.57	502635	0.55
MING PLENTY	1.08	1.00	867	800	12.81	11102	10248	0.012	0.011	63.58	13.57	474642	0.52
MOKIHANA	0.75	0.72	1500	1433	12.81	19215	18361	0.021	0.020	38.62	13.57	720671	0.79
N O L RUBY	0.92	0.90	807	792	12.81	10333	10146	0.011	0.011	41.10	13.57	337487	0.37
N O L ZIRCON	0.95	0.95	836	836	12.81	10709	10709	0.012	0.012	74.72	13.57	613526	0.68
NEPTUNE JADE	1.08	0.62	867	493	12.81	11102	6320	0.012	0.007	10.80	13.57	80621	0.09
NYK SEABREEZE	1.10	0.92	1320	1100	12.81	16909	14091	0.019	0.016	19.25	13.57	215548	0.24
OOCL AMERICA	0.67	0.70	1120	1176	12.81	14347	15065	0.016	0.017	76.80	13.57	1203935	1.33
SEA-LAND CHARGER	0.62	0.42	1085	733	12.81	13903	9394	0.015	0.010	26.00	13.57	426991	0.47
SEA-LAND GUATEMALA	0.55	0.38	612	426	12.81	7835	5460	0.009	0.006	15.32	13.57	158928	0.18
SEA-LAND PATRIOT	0.85	2.25	884	2340	12.81	11324	29975	0.012	0.033	55.82	13.57	541664	0.60
SOVCOMFLOT SENATOR	0.67	0.42	640	400	12.81	8198	5124	0.009	0.006	28.92	13.57	259031	0.29
VLADIVOSTOK SENATOR	0.60	0.50	576	480	12.81	7379	6149	0.008	0.007	33.65	13.57	301432	0.33
YURIY OSTROVSKIY	0.67	0.47	533	373	12.81	6832	4782	0.008	0.005	1.53	13.57	11446	0.01
ZIM AMERICA	0.82	0.72	810	711	12.81	10378	9107	0.011	0.010	17.37	13.57	160754	0.18
ZIM CANADA	0.57	0.55	562	546	12.81	7201	6989	0.008	0.008	7.17	13.57	66338	0.07
CHEVRON COLORADO	1.03	0.75	1819	1320	12.81	23297	16909	0.026	0.019	35.30	13.57	579722	0.64
CHEVRON OREGON	0.75	0.75	1320	1320	12.81	16909	16909	0.019	0.019	0.17	13.57	2737	0.00
ARCO INDEPENDENCE*													
ARCO PRUDHOE BAY*													
ARCO SAG RIVER*													
ARCO SPIRIT*													
BLUE RIDGE*													
FREDERICKSBURG*													
MARINE CHEMIST*													
EWA*													
KAUAI*													
SEA-LAND CHALLENGER*													
MATSONIA*													

Generator Calculations for Steamships are not applicable*

Table B-2

U.S. Navy Vessel Inventory

								Reported in Greenwich Mean Time											
Ship Class	Ship Type	Average Ship Speed (Knots)	Longitude 1	Latitude 1	Longitude 2	Latitude 2	Port Visited (at pierside)	Time 1 Hrs	Time 1 Min	Time 2 Hrs	Time 2 Min	Time Duration (Hrs)	Start Date	End Date	NOx Kg/Hr	SOx Kg/Hr	HC Kg/Hr	CO Kg/Hr	PM Kg/Hr
FFG 7	Frigate																		
1		0.00	117.17	32.72	117.17	32.72	San Diego	7	0	13	51	6.85	8/3/97	8/4/97	Cold Iron (No Emissions)				
2		15.83	117.17	32.72	117.53	33.05		13	51	16	0	2.15	8/4/97	8/4/97	29.53	17.45	5.55	69.31	2.12
3		20.86	117.53	33.05	118.10	33.72		16	0	19	59	3.98	8/4/97	8/4/97	34.49	22.40	4.00	49.75	2.35
4		0.00	118.10	33.72	118.10	33.72	Seal Beach	19	59	21	54	25.91	8/4/97	8/5/97	Cold Iron (No Emissions)				
5		13.96	118.10	33.72	118.15	33.58		21	54	23	59	2.08	8/5/97	8/5/97	28.52	16.35	5.97	74.49	2.07
6		5.19	118.15	33.58	117.63	33.13		23	59	8	0	8.00	8/5/97	8/6/97	26.43	13.97	6.99	86.85	1.96
7		6.57	117.63	33.13	117.17	32.72		8	0	16	4	8.07	8/6/97	8/6/97	26.56	14.12	6.92	86.05	1.97
8		0.00	117.17	32.72	117.17	32.72	San Diego	16	4	7	0	14.93	8/6/97	8/8/97	Cold Iron (No Emissions)				
LSD 36	Auxiliary																		
1		0.00	117.17	32.72	117.17	32.72	San Diego	7	0	15	31	32.52	8/3/97	8/4/97	Cold Iron (No Emissions)				
2		7.62	117.17	32.72	117.47	32.62		15	31	19	0	3.45	8/4/97	8/4/97	3.81	11.46	0.48	0.65	2.42
3		11.41	117.47	32.62	117.17	32.72		19	0	22	59	3.98	8/4/97	8/4/97	5.75	17.30	0.73	0.97	3.65
4		0.00	117.17	32.72	117.17	32.72	San Diego	22	59	15	34	0.00	8/4/97	8/6/97	Cold Iron (No Emissions)				
5		10.00	117.17	32.72	117.18	32.58		15	34	16	0	0.43	8/6/97	8/6/97	4.91	14.76	0.62	0.83	3.12
6		10.13	117.18	32.58	117.23	32.58		16	0	17	0	1.00	8/6/97	8/6/97	4.98	14.97	0.63	0.84	3.16
7		3.90	117.23	32.58	117.41	32.67		17	0	19	0	2.00	8/6/97	8/6/97	2.31	6.96	0.29	0.39	1.47
8		10.67	117.41	32.67	117.57	32.83		19	0	3	0	8.00	8/6/97	8/7/97	5.28	15.90	0.67	0.90	3.36
9		6.30	117.57	32.83	117.58	32.80		3	0	19	0	16.00	8/7/97	8/7/97	3.29	9.89	0.42	0.56	2.09
10		12.83	117.58	32.80	117.48	32.58		19	0	20	0	1.00	8/7/97	8/7/97	6.82	20.51	0.87	1.16	4.33
11		9.46	117.48	32.58	117.17	32.72		20	0	22	47	2.78	8/7/97	8/7/97	4.63	13.92	0.59	0.78	2.94
12		0.00	117.17	32.72	117.17	32.72	San Diego	22	47	7	0	8.22	8/7/98	8/8/97	Cold Iron (No Emissions)				
DD 963	Destroyer																		
1		0.00	117.17	32.72	117.17	32.72	San Diego	7	0	14	24	45.40	8/3/97	8/5/97	Cold Iron (No Emissions)				
2		4.63	117.17	32.72	117.31	32.62		14	24	15	0	0.60	8/5/97	8/5/97	24.89	27.12	11.95	166.21	2.88
3		8.58	117.31	32.62	117.22	32.65		15	0	16	0	1.00	8/5/97	8/5/97	27.83	30.52	10.45	148.12	3.03
4		5.35	117.22	32.65	117.96	32.61		16	0	19	0	3.00	8/5/97	8/5/97	25.22	27.52	11.76	164.03	2.89
5		9.29	117.96	32.61	118.37	32.37	Leaving Zone	19	0	21	48	2.80	8/5/97	8/5/97	28.67	31.46	10.07	143.42	3.07
6		15.83	118.37	32.37	118.67	32.37	Out of Zone	21	48	23	48	2.00	8/5/97	8/5/97	Cold Iron (No Emissions)				
7		1.45	118.67	32.37	118.67	32.62	Returning to Zone	23	48	3	0	3.20	8/5/97	8/6/97	24.45	26.60	12.19	169.15	2.85
8		3.56	118.67	32.62	118.56	32.46		3	0	15	0	12.00	8/6/97	8/6/97	24.55	26.72	12.13	168.45	2.86
9		6.21	118.56	32.46	118.10	32.69		15	0	19	0	4.00	8/6/97	8/6/97	25.73	28.12	11.49	160.74	2.92
10		7.18	118.10	32.69	117.64	32.85		19	0	3	0	8.00	8/6/97	8/7/97	26.47	28.97	11.11	156.18	2.96